

HIGH RESOLUTION CLIMATE INFORMATION FOR MOUNTAIN AREAS (HR-CIMA)



Michele Brunetti
m.brunetti@isac.cnr.it

Istituto di Scienze dell'Atmosfera e del Clima
Consiglio Nazionale delle Ricerche



03-04 Giugno 2014 – ROMA

High Resolution Climate Information for Mountain Areas (HR-CIMA)

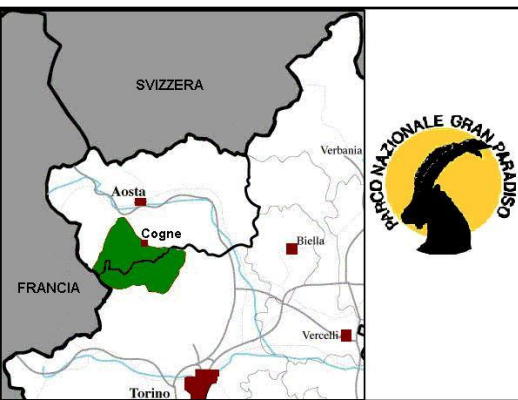
Obiettivi:

- Realizzazione di climatologie mensili ad alta risoluzione (30 secondi d'arco) di precipitazioni e temperature (1961-1990) per la regione alpina italiana ($h > 1500\text{m}$)

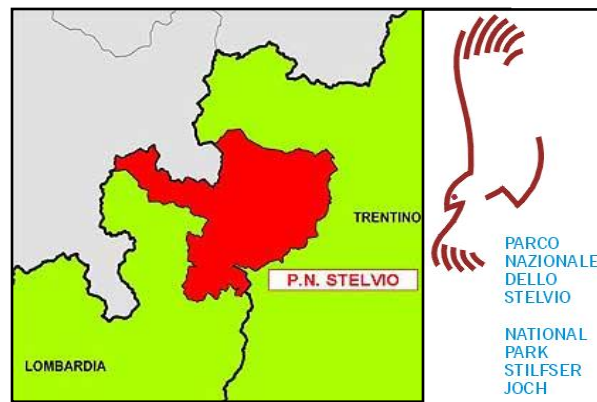


- Realizzazione di data set di serie temporali di precipitazioni e temperature alla medesima risoluzione spaziale per tre aree studio:

PARCO DEL GRAN PARADISO



PARCO DELLO STELVIO



PARCO DI PANEVEGGIO E PALE DI SAN MARTINO



APPROCCIO AL PROBLEMA

COSTRUIRE SEPARATAMENTE:

(Mitchell and Jones, 2005. *Int J Clim*, 25, 693-712)

I VALORI NORMALI (CLIMATOLOGIE)

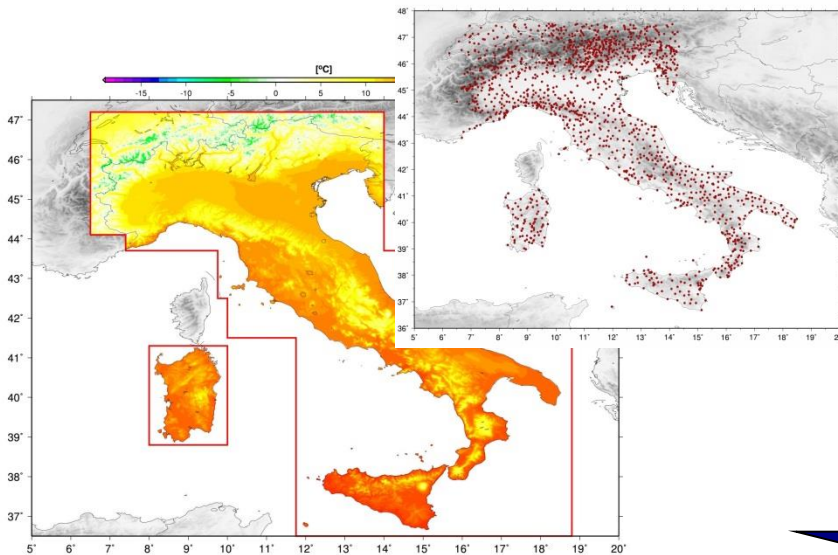
- **LE CLIMATOLOGIE** SONO CARATTERIZZATE DA FORTI GRADIENTI SPAZIALI, QUINDI SERVIRA' UN'**ALTA DENSITA' DI STAZIONI** PER RAPPRESENTARLE, TUTTAVIA **SARA' SUFFICIENTE UN TRENTENNIO DI DATI** PER VALUTARLE LE NORMALI CLIMATICHE

E

LE DEVIAZIONI DA QUESTI

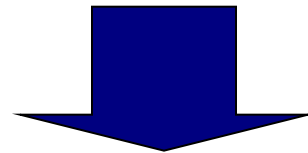
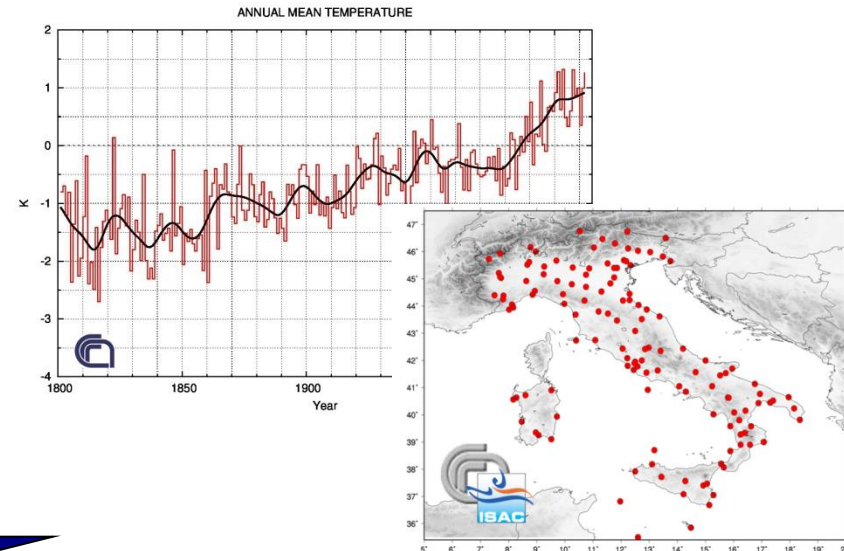
- **LE DEVIAZIONI** DA QUESTE SONO PIU' COERENTI SPAZIALMENTE, QUINDI SERVIRANNO **MENO STAZIONI** PER POTERLE RAPPRESENTARE, MA SARA' NECESSARIA UNA **PIU' LUNGA ESTENSIONE TEMPORALE** PER UNA PROFICUA ANALISI DI TENDENZE A LUNGO TERMINE

**Climatologia ad alta risoluzione
(1kmX1km)**



+

**Griglia anomalie da serie storiche
(50-150 anni)**



Dalla sovrapposizione di climatologie e anomalie otteniamo griglie di soluzione 1kmX1km di variabili meteorologiche in valori assoluti per gli ultimi decenni/secoli (a seconda della disponibilità di lunghe serie).

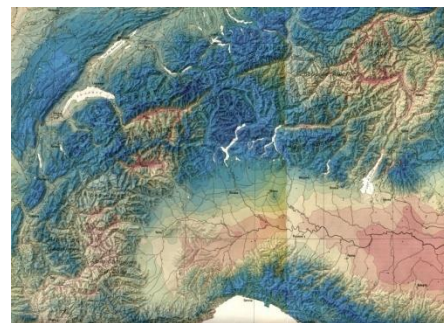
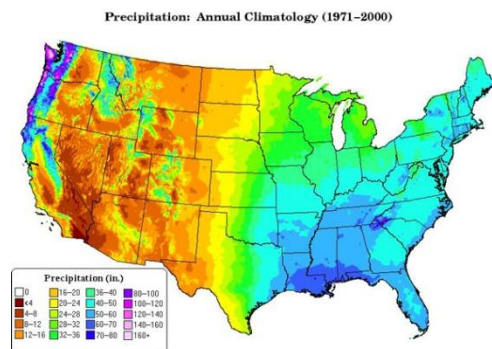
COSTRUZIONE DELLE CLIMATOLOGIE

PER LA COSTRUZIONE DI CLIMATOLOGIE AD ALTA RISOLUZIONE OCCORRONO:

- **UNA PROCEDURA ADEGUATA** PER CATTURARE LA CORRETTA DIPENDENZA DELLA VARIABILE DAI PARAMETRI GEOMORFOLOGICI
- **UN DATA SET ADEGUATO** CHE CI PERMETTA DI DESCRIVERE I GRADIENTI SPAZIALE ALLA RISOLUZIONE CHE ABBIAMO SCELTO

THE MODEL

THE SELECTED MODEL IS SIMILAR TO **PRISM** (Parameter-elevation regression on independent slopes model) ALREADY USED FOR **US** (Daly et al., 1994) AND THE **ALPINE REGION** (Frei and Schär, 1998).



LOCAL PARAMETER vs ELEVATION WEIGHTED LINEAR REGRESSION (LWLR)

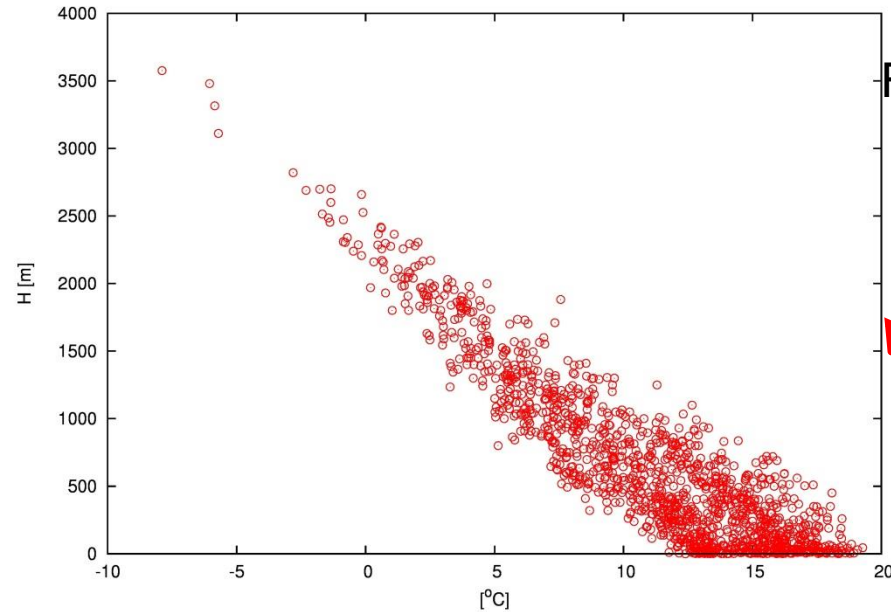
WHY THIS MODEL?

Daly C, Neilson RP, Philipps DL. 1994. Journal of Applied Meteorology, 33: 140-158

Frei C., Schär C. 1998. International Journal of climatology, 18: 873-900.

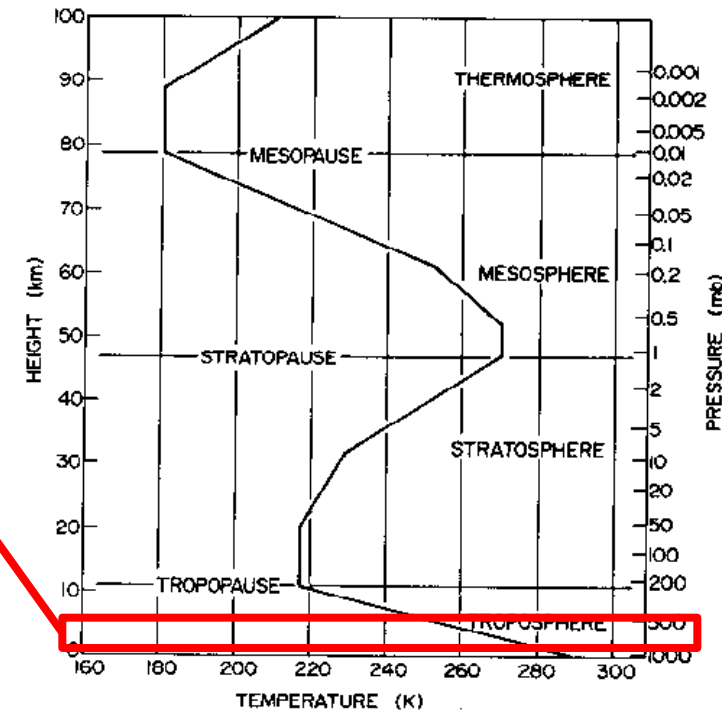
TEMPERATURE

For temperature it is quite obvious. Temperature decrease with elevation in the troposphere.



However the **lapse rate is locally different** depending on various factors:

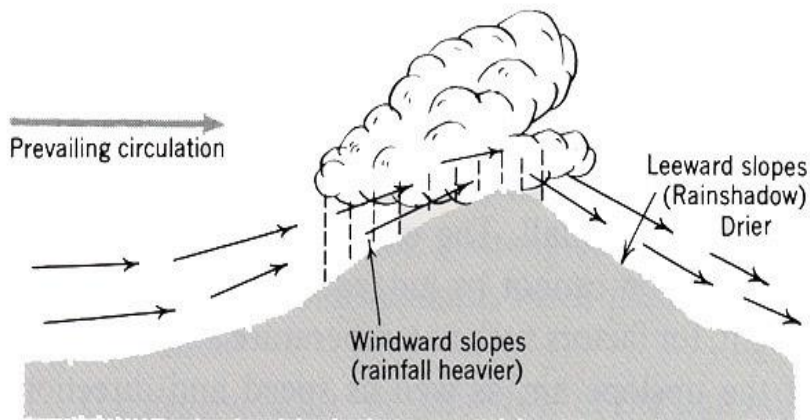
- Total solar radiation received (i.e. slope orientation and steepness)
- Sea mitigating effect
- Pool air cooling (i.e. temperature inversion effect)



FOR THESE REASONS A GLOBAL T vs H RELATIONSHIP IS NOT APPROPRIATE, BUT A LOCAL ESTIMATION OF THE LAPSE RATE IS BETTER

PRECIPITATION

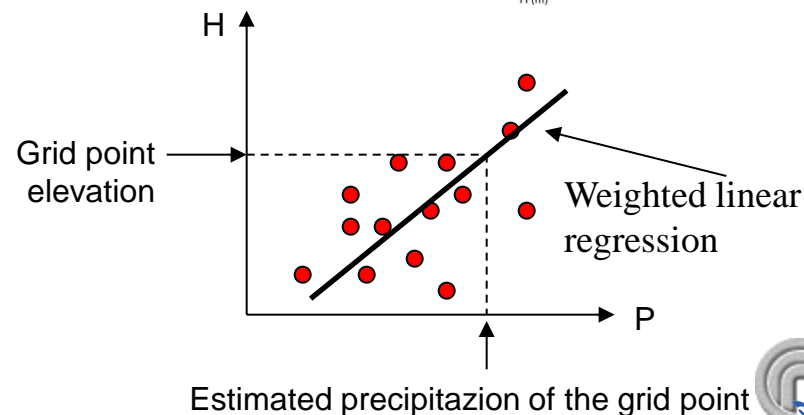
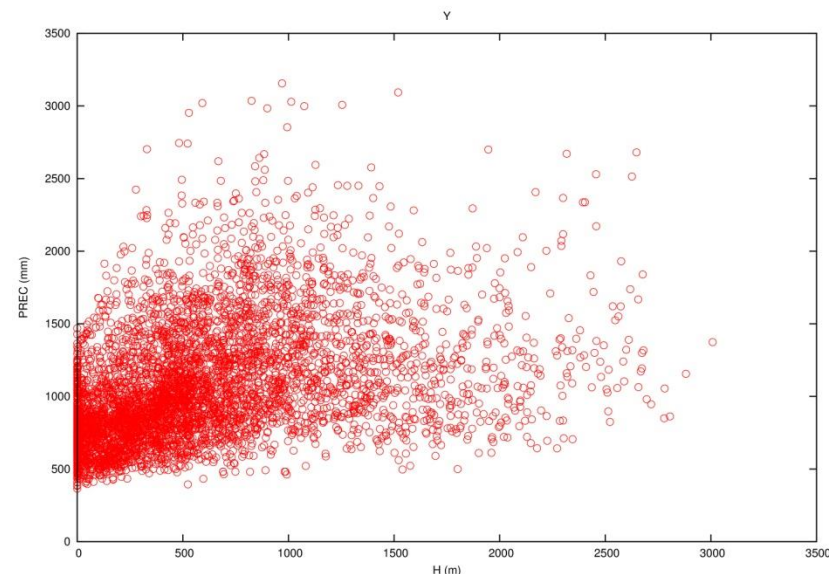
Why this model?: because precipitation is strongly linked to orography, with a general increase of precipitation with elevation and with strong differences between windward and leeward slopes.... but....



... the link among precipitation and elevation is highly site dependent...

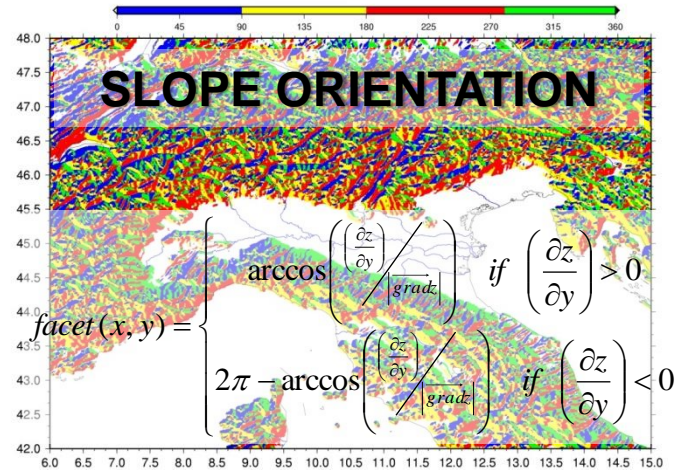
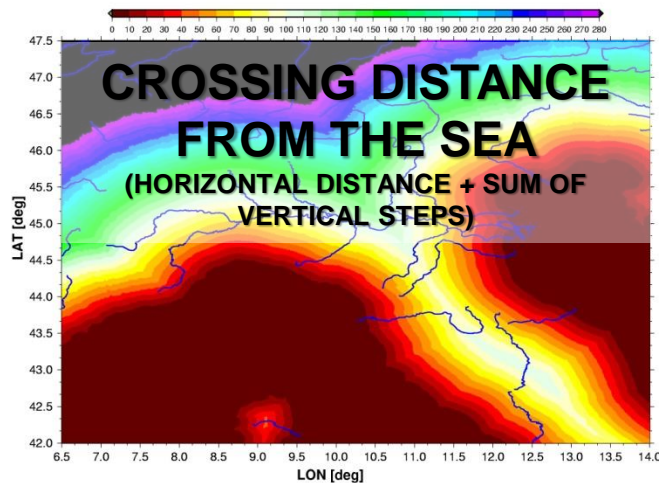
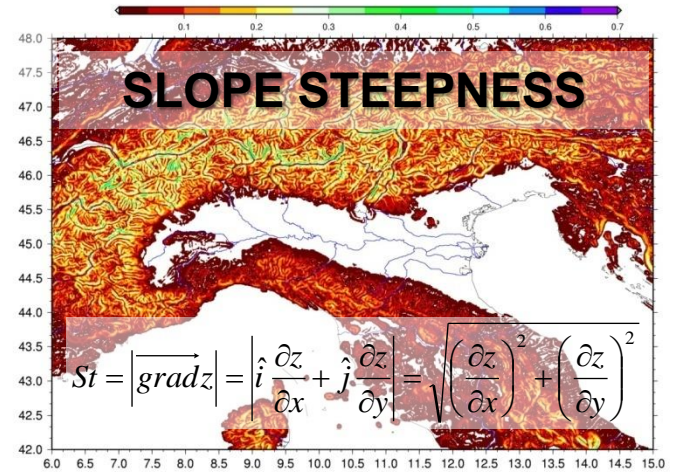
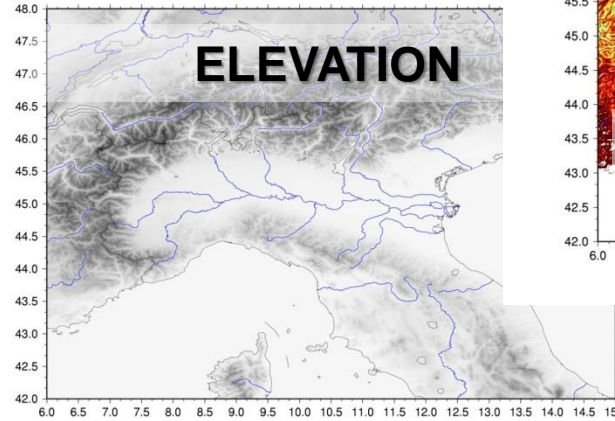
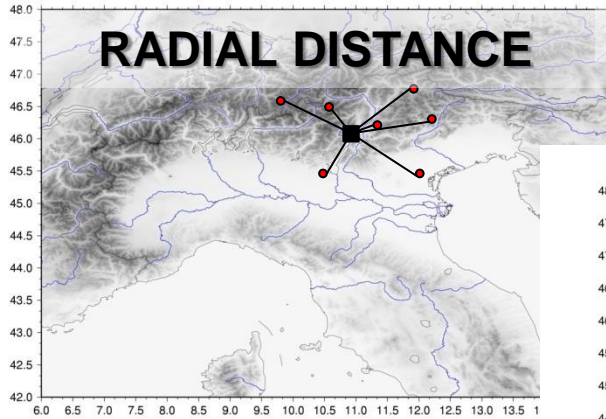
So such a link has to be investigated on small spatial scales.

How can such a study be performed? By means of a weighted linear regression of precipitation and elevation, being the weights given by the similarity between the geographic characteristics of each station and the grid cell.



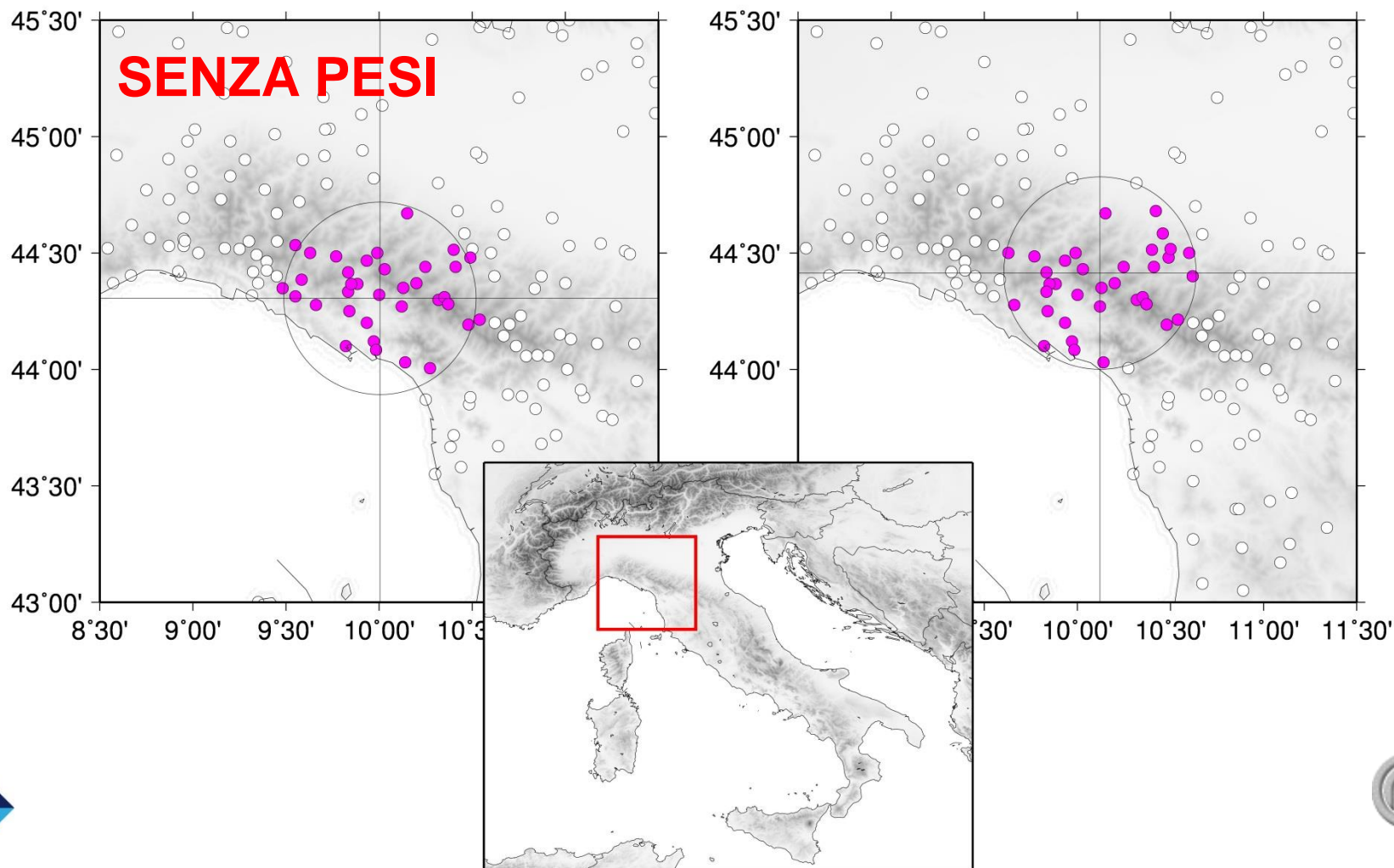
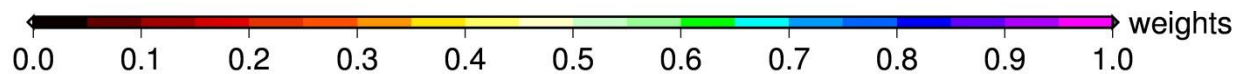
LA METODOLOGIA PER LA COSTRUZIONE DELLE CLIMATOLOGIE

THE WEIGHTS

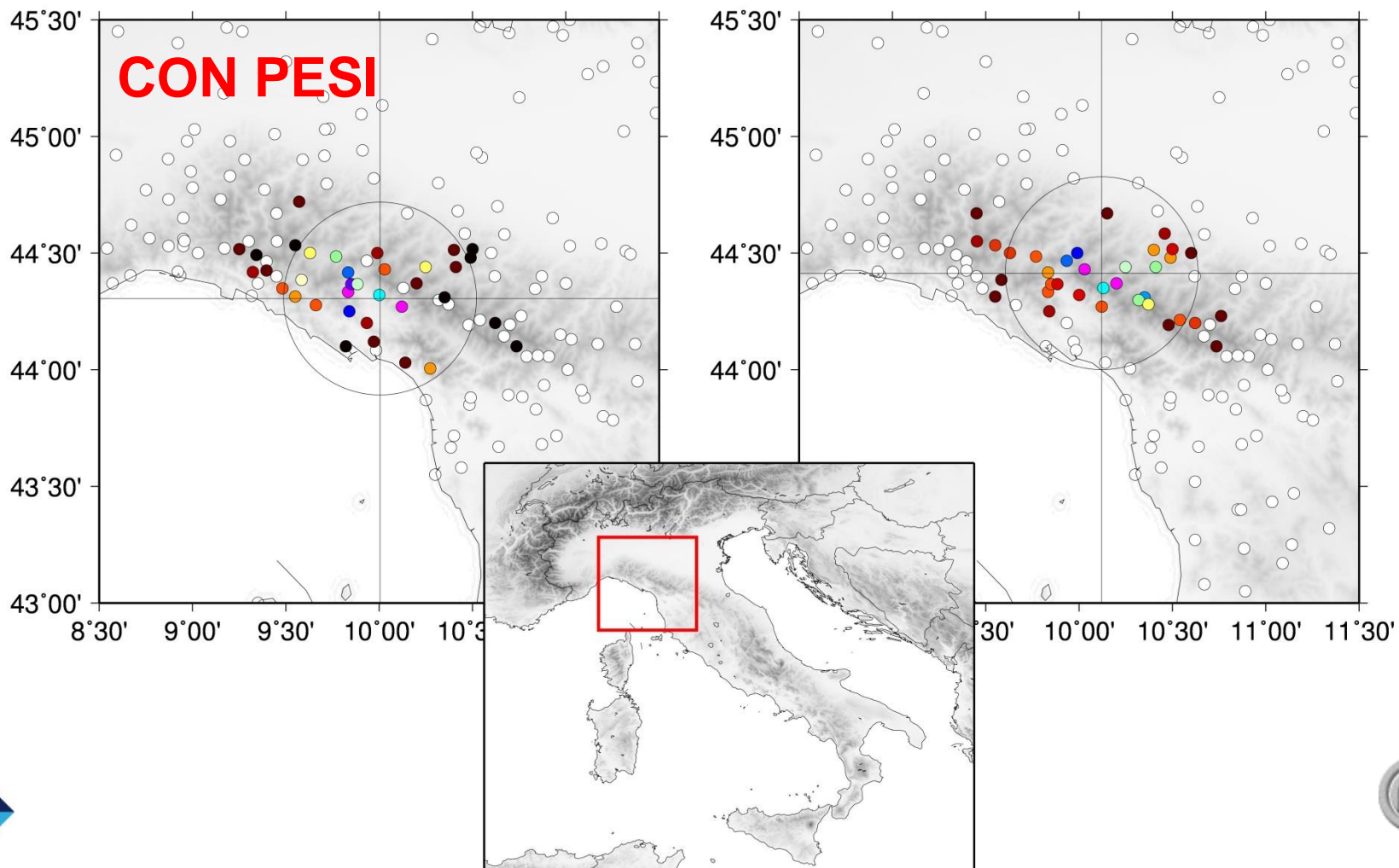
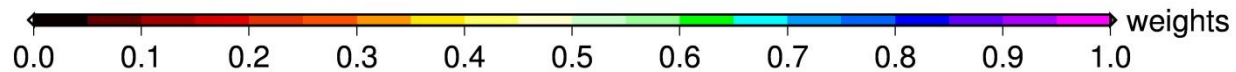


$$w_i(x, y) = w_i^{rad}(x, y) \cdot w_i^h(x, y) \cdot w_i^{St}(x, y) \cdot w_i^{facet}(x, y) \cdot w_i^{sea}(x, y)$$

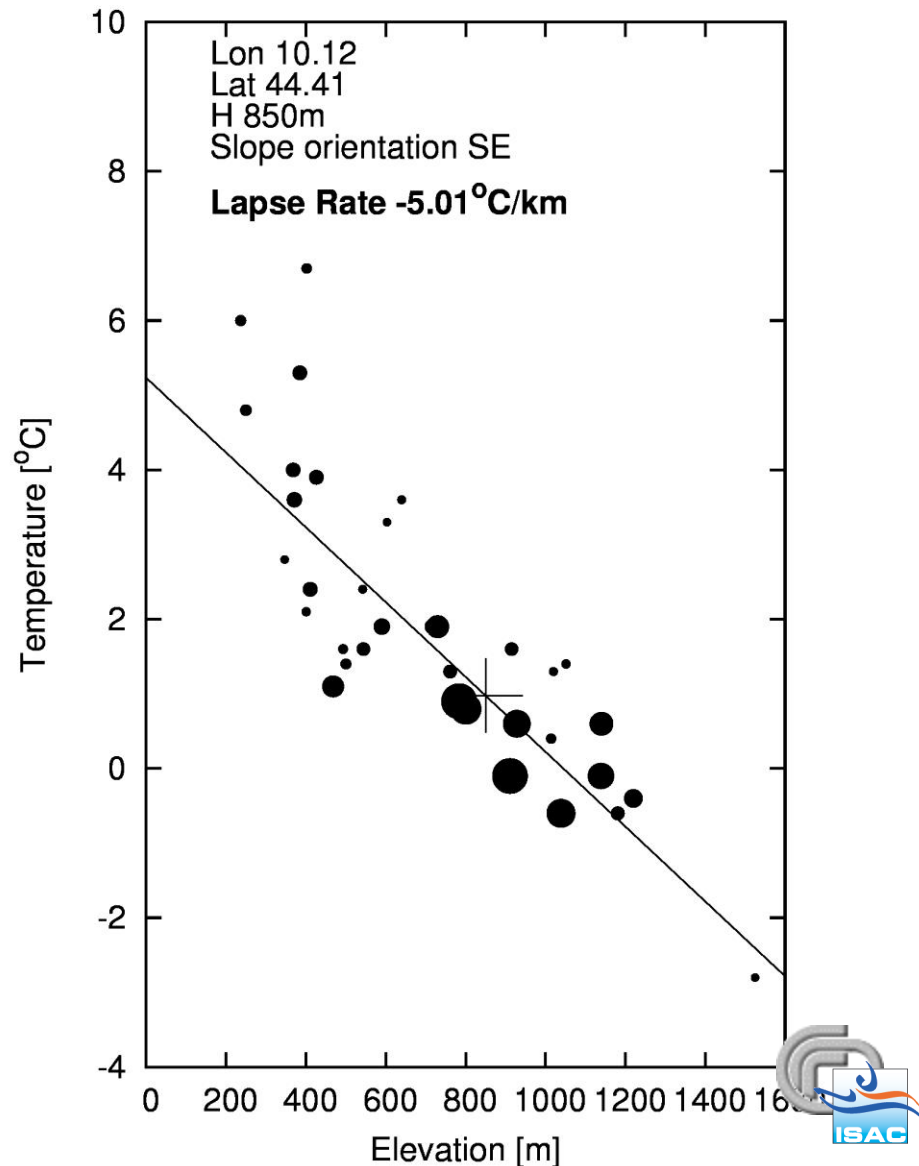
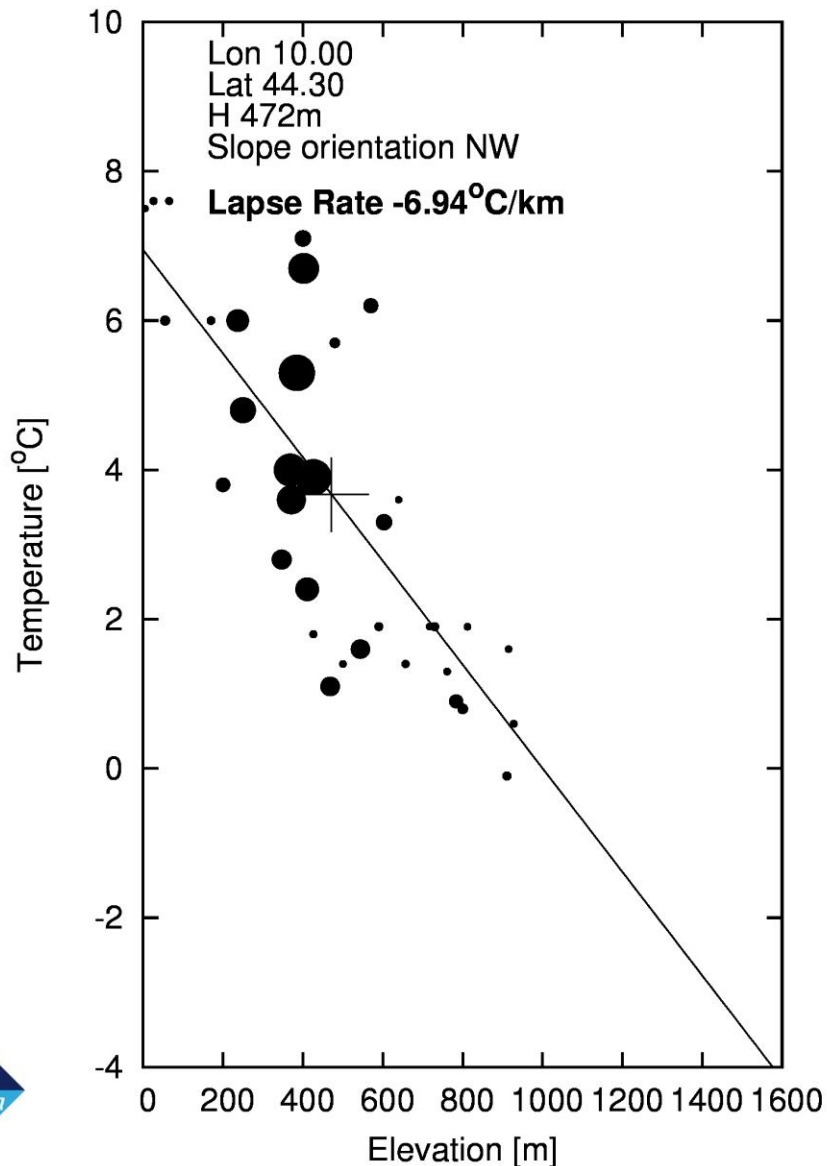
L'IMPORTANZA DEI PESI



L'IMPORTANZA DEI PESI

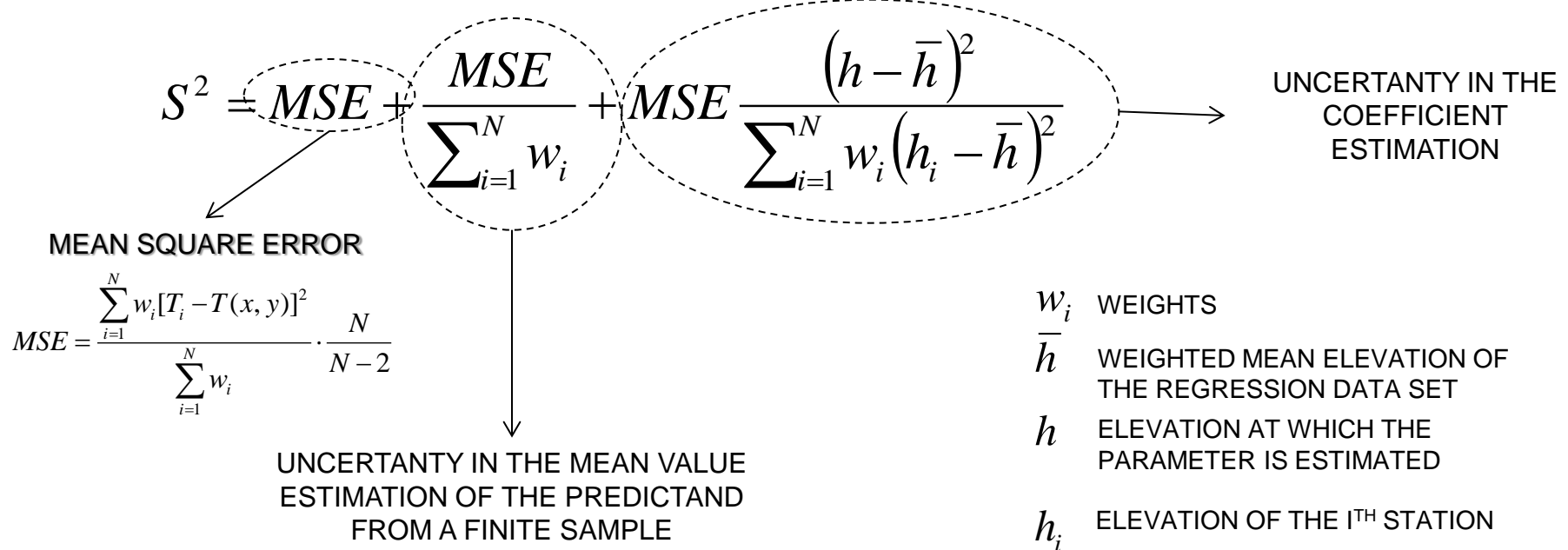


L'IMPORTANZA DEI PESI



INTERVALLO DI CONFIDENZA

IMPORTANT ADVANTAGE OF LWLR: **CONFIDENCE INTERVAL**



The prediction interval for the grid-point with elevation h is

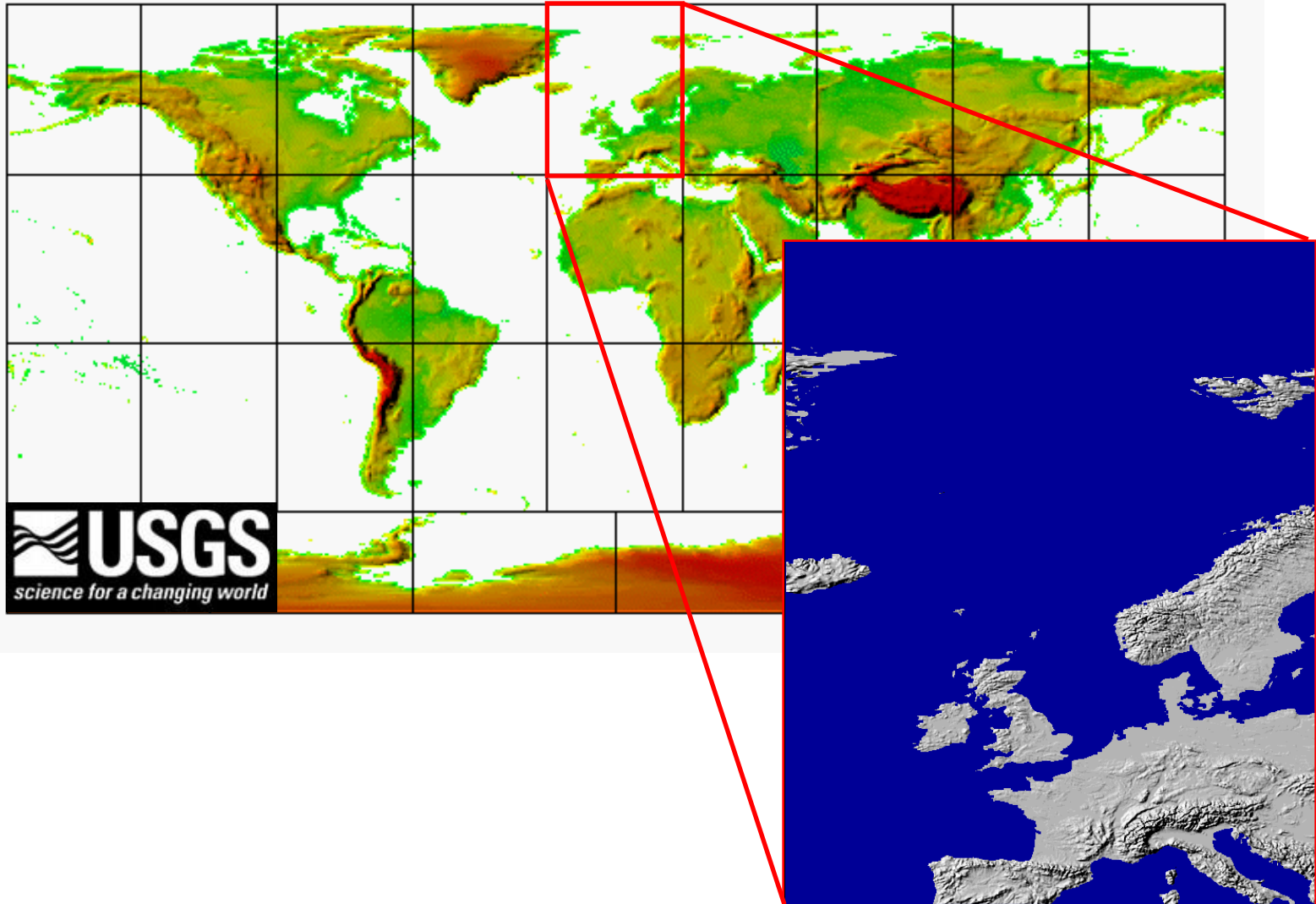
$$T_h \pm t_{\frac{1-\alpha}{2}, df} \cdot s\{T_h\}$$

where t is the value of a Student distribution with df degrees of freedom corresponding to cumulative probability $(1-\alpha)/2$.

I DATI PER LA COSTRUZIONE DELLA CLIMATOLOGIA

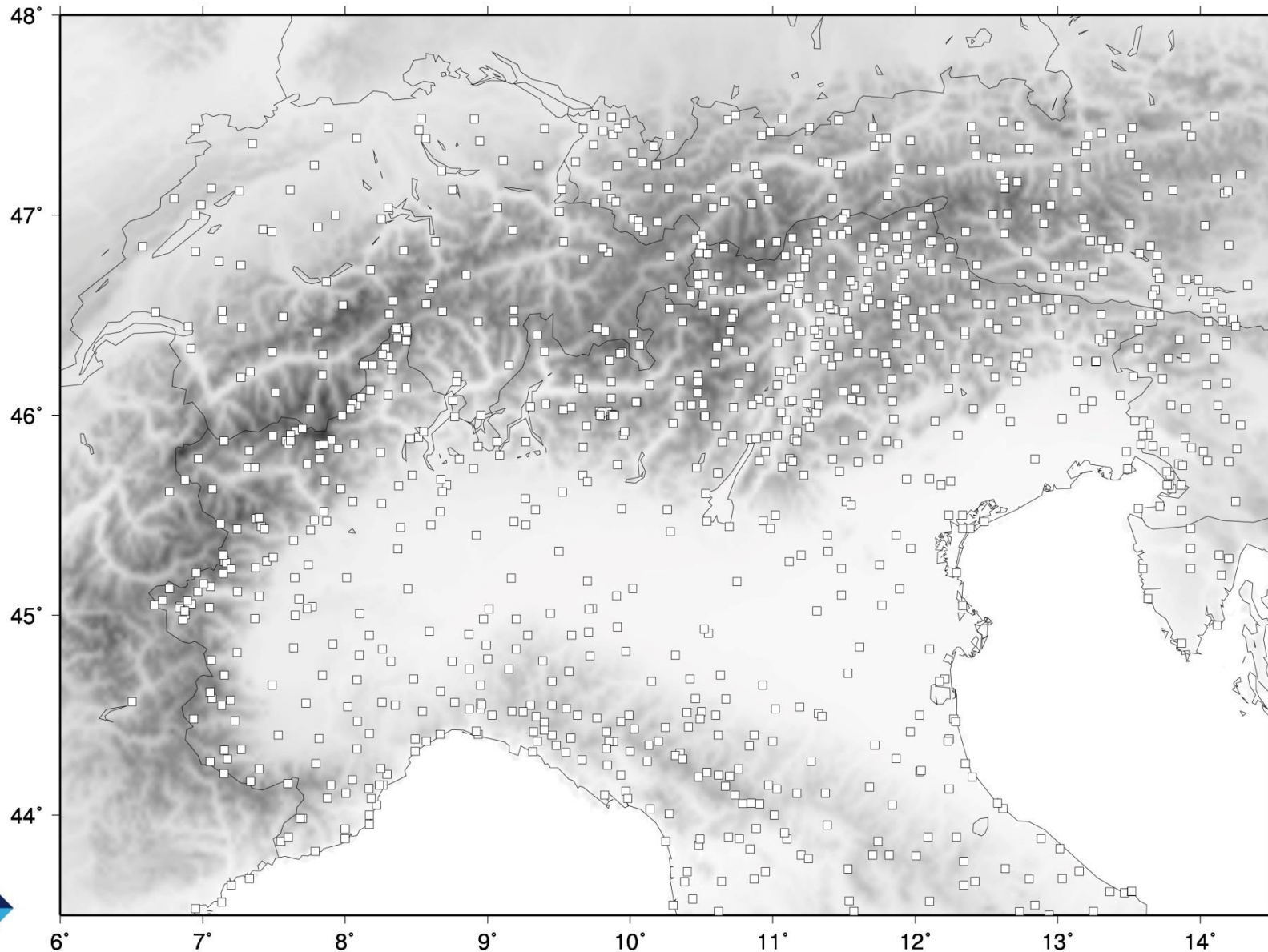
I DATI PER LA COSTRUZIONE DELLA CLIMATOLOGIA

30 arcseconds Digital Elevation Model



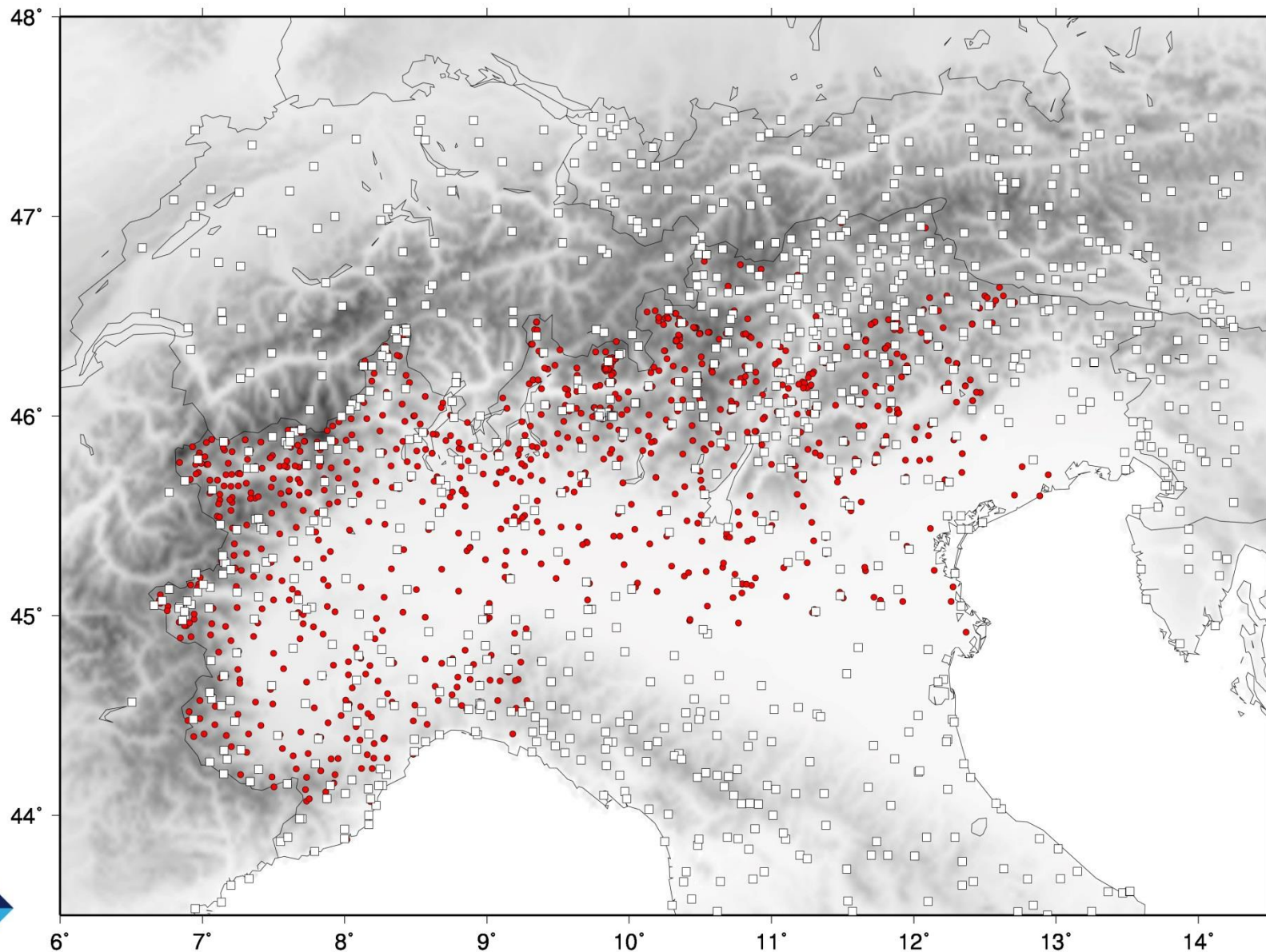
I DATI PER LA COSTRUZIONE DELLA CLIMATOLOGIA

TEMPERATURE (disponibilità prima di NextData)



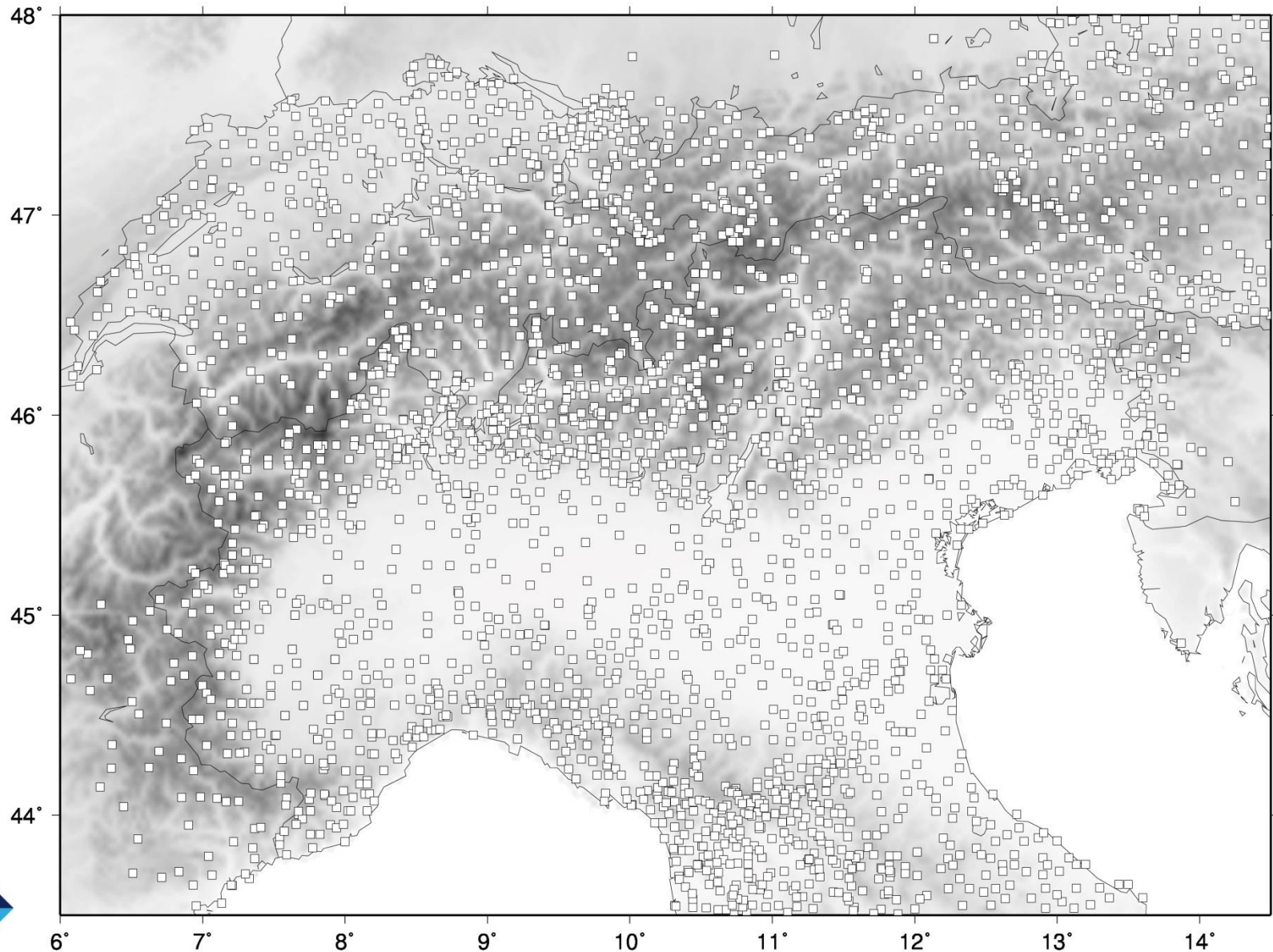
I DATI PER LA COSTRUZIONE DELLA CLIMATOLOGIA

TEMPERATURE (data rescue nell'ambito di NextData)



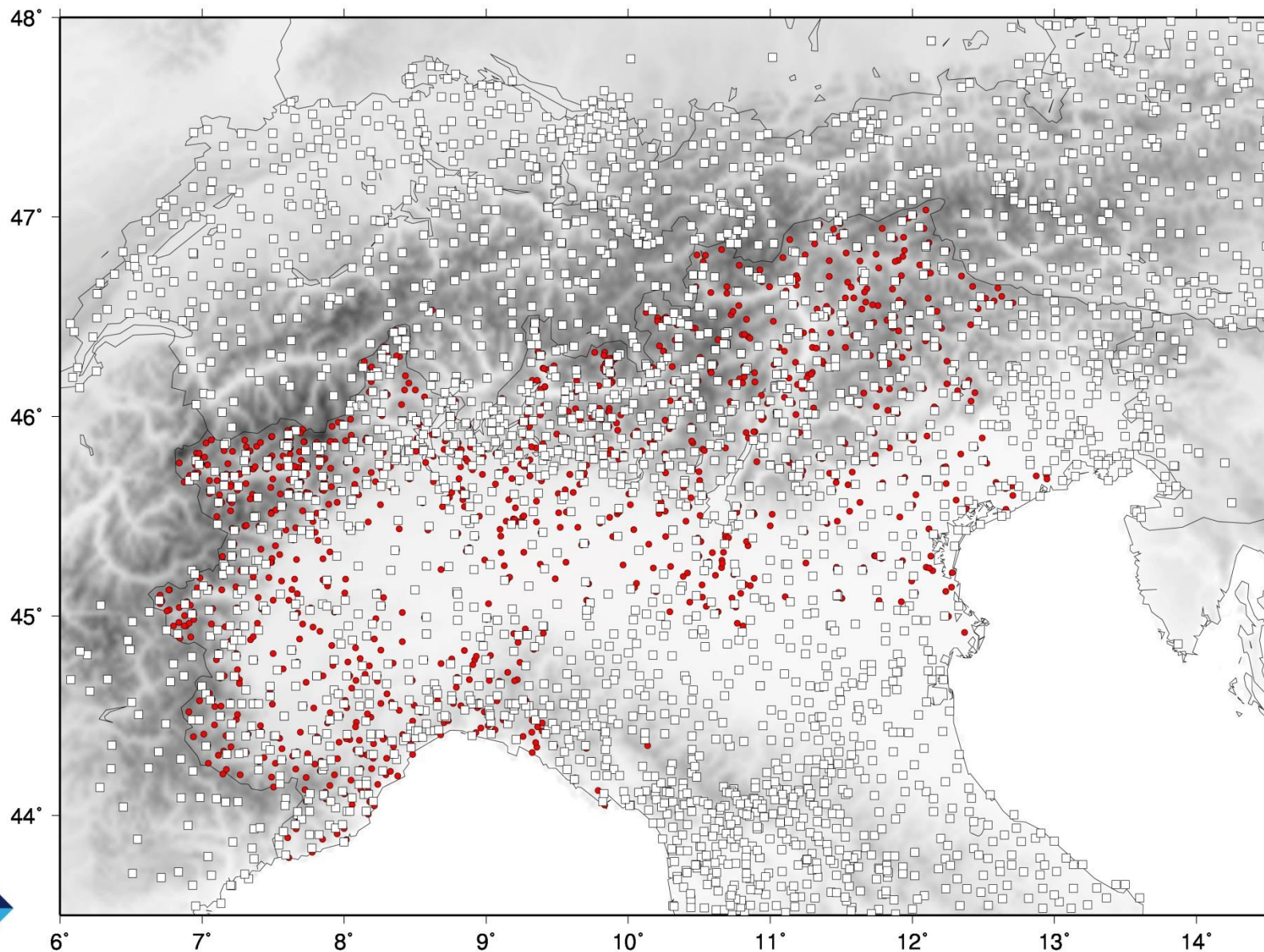
I DATI PER LA COSTRUZIONE DELLA CLIMATOLOGIA

PRECIPITAZIONI (disponibilità prima di NextData)



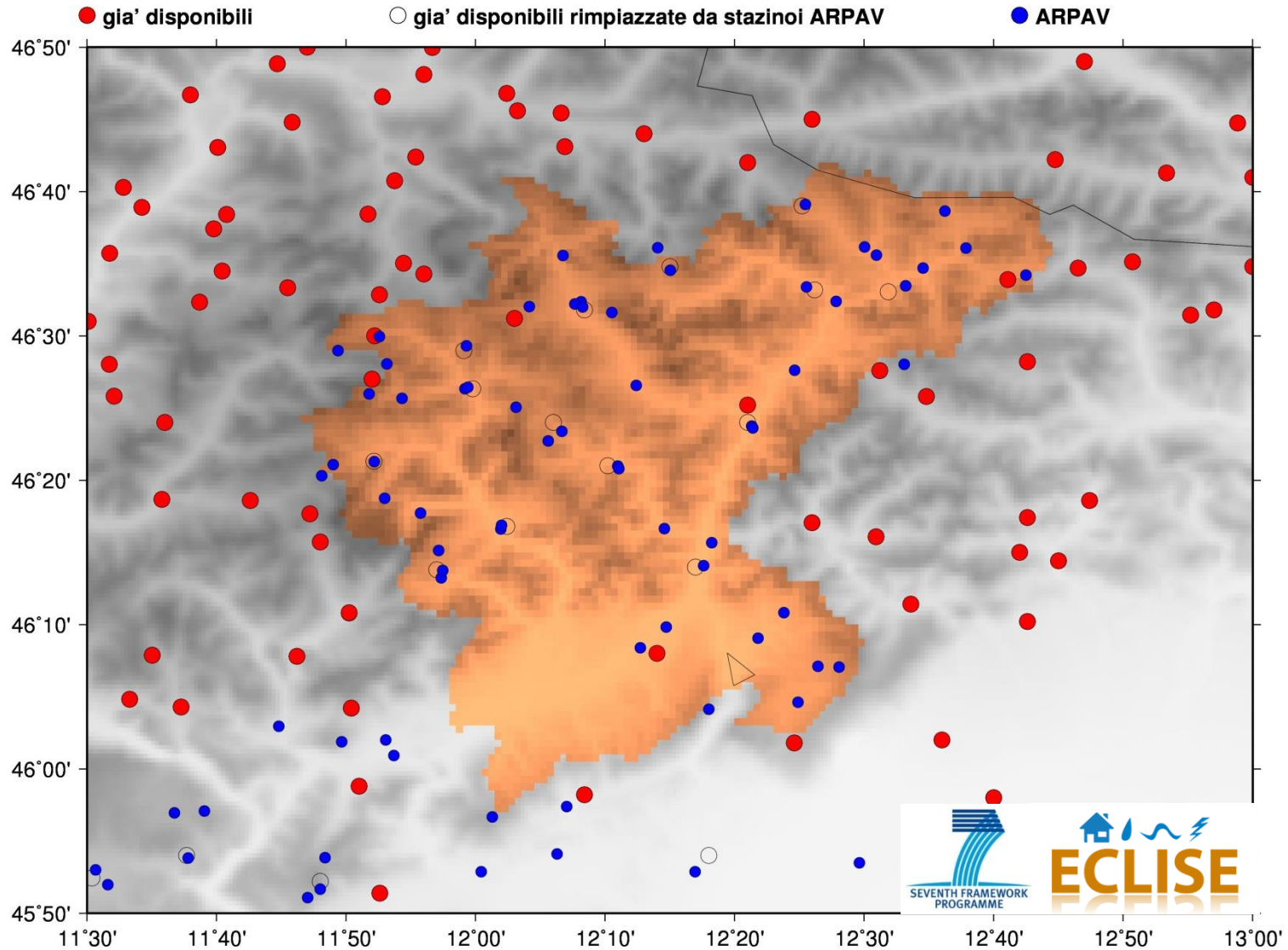
I DATI PER LA COSTRUZIONE DELLA CLIMATOLOGIA

PRECIPITAZIONI (data rescue nell'ambito di NextData)



ALCUNI RISULTATI

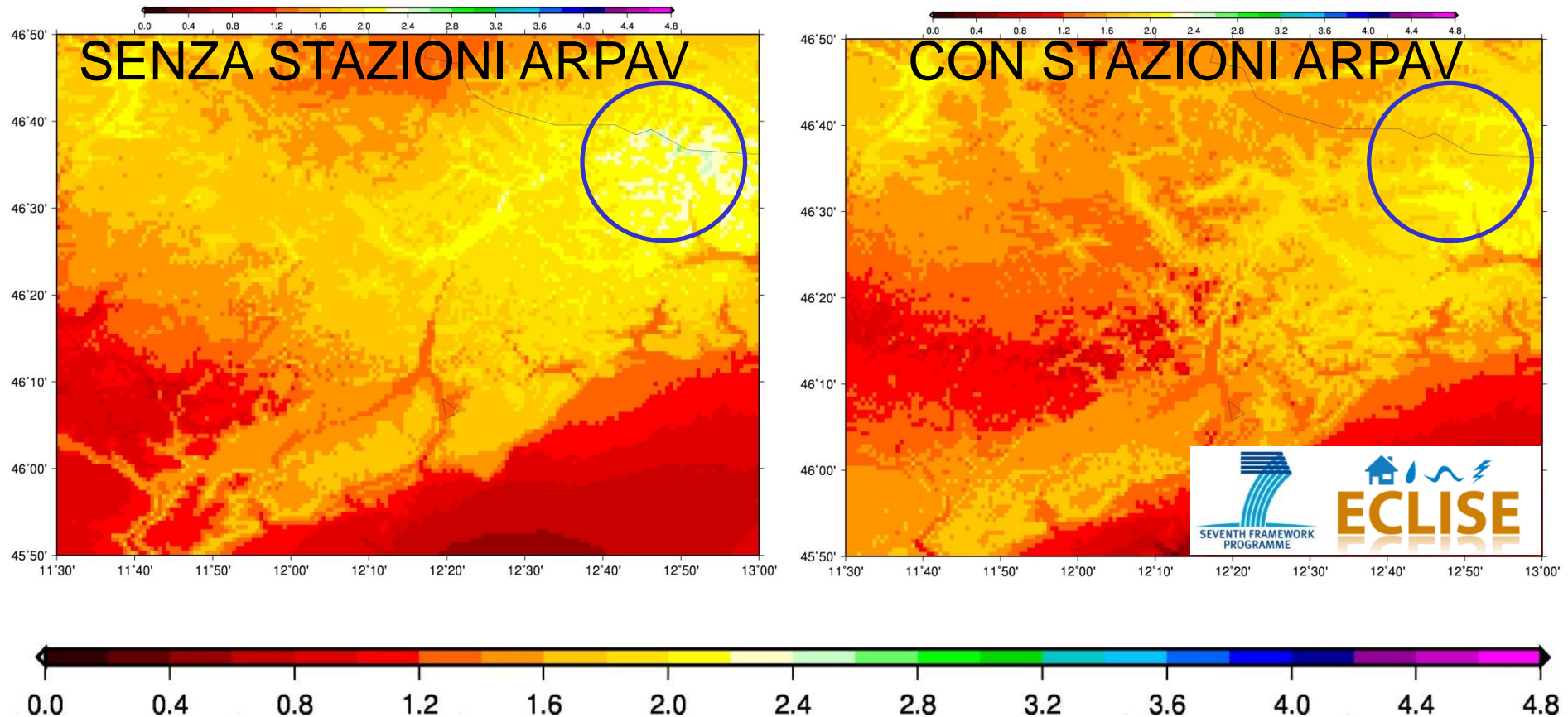
Migliorando la disponibilità di dati...



ALCUNI RISULTATI

...migliora la qualità della ricostruzione e la confidenza sui risultati

INTERVALLO DI CONFIDENZA $\alpha=0.6827$



La disponibilità delle stazioni di ARPA Veneto ha permesso un miglioramento dell'intervallo di confidenza.

Questo è particolarmente evidente nelle zone di alta quota, grazie soprattutto alla maggior rappresentatività delle stazioni ARPAV per quelle aree.

COSTRUZIONE DELLE ANOMALIE

COSTRUZIONE DELLE ANOMALIE

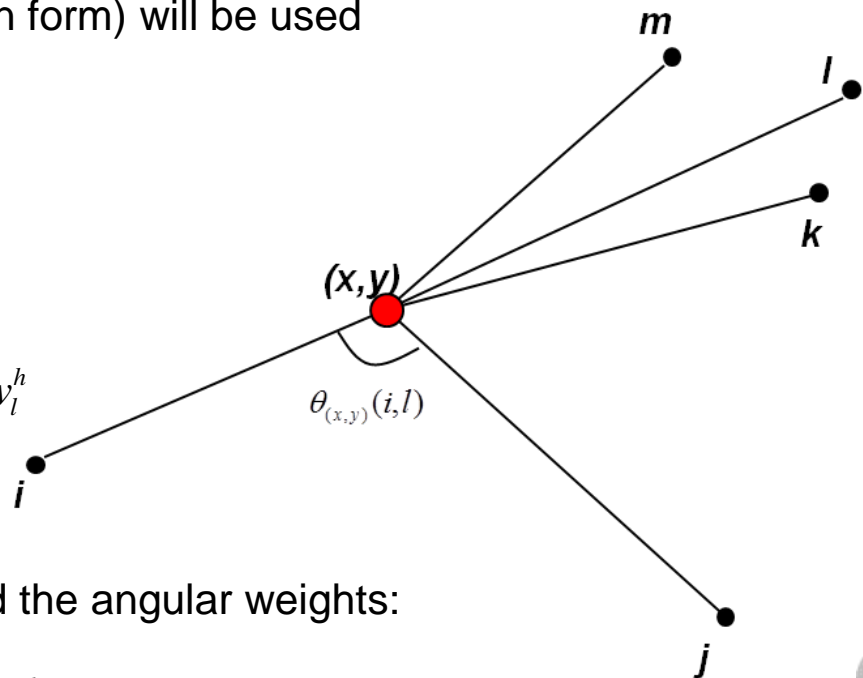
Thanks to the high spatial coherence of temporal fluctuations of meteorological variables, anomalies can be reconstructed on each point of a high resolution grid with a quite simple method.

$w_i^{rad}(x, y) = e^{-\left(\frac{d_i^2(x, y)}{c_{rad}}\right)}$ An inverse horizontal distance weighting function (of Gaussian form) will be used

$w_i^h(x, y) = e^{-\left(\frac{\Delta h_i^2(x, y)}{c_h}\right)}$ An inverse elevation distance weighting function (of Gaussian form) will be used

An angular weight is also used to take into account spatial anisotropy in station location:

$$w_i^{ang}(x, y) = 1 + \frac{\sum_{l=1}^n w_l' [1 - \cos \theta_{(x, y)}(i, l)]}{\sum_{l=1}^n w_l'(x, y)}; \quad w_l' = w_l^{rad} w_l^h$$



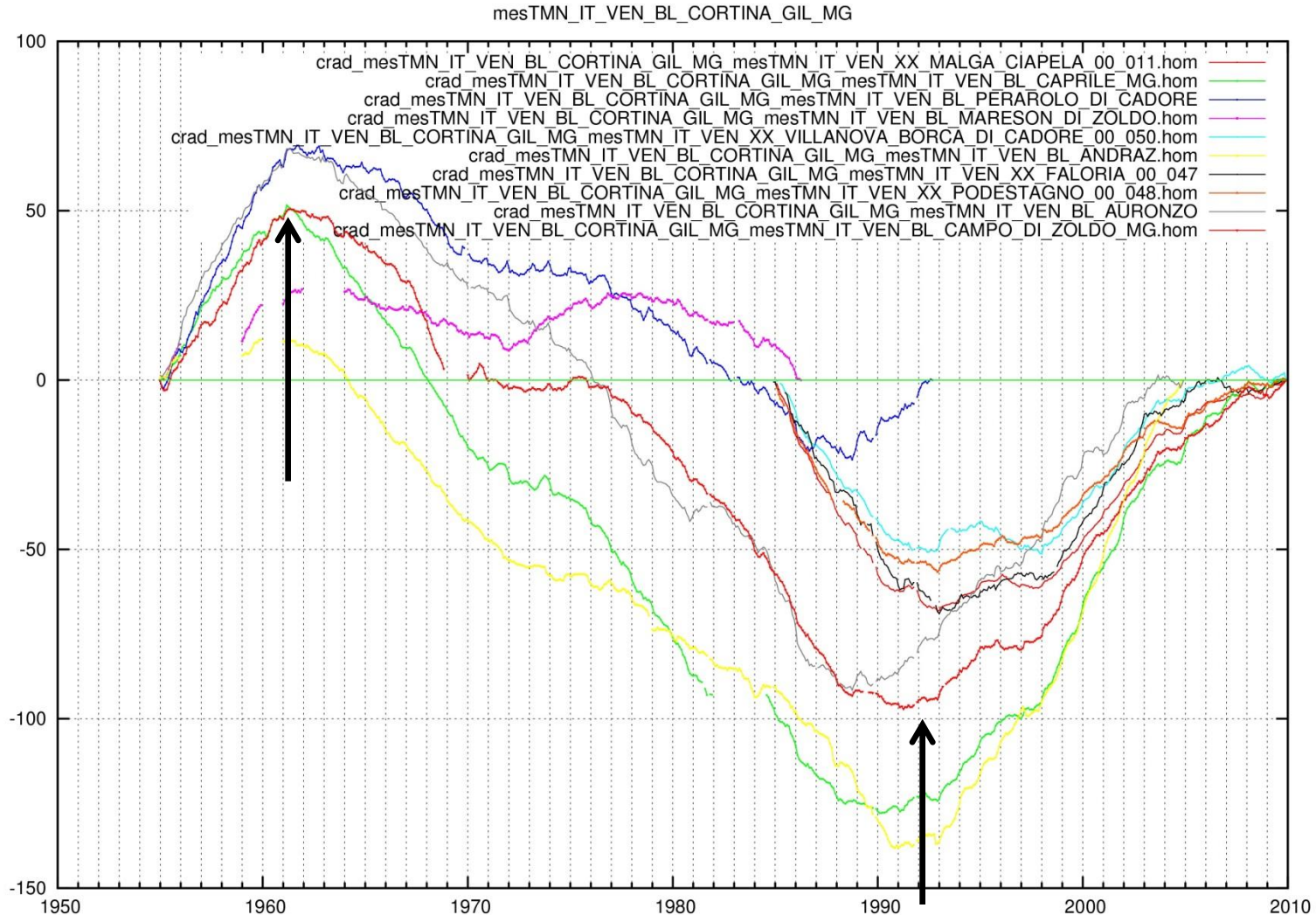
The final weight is the product of the radial and the angular weights:

$$w_i(x, y) = w_i^{rad}(x, y) \cdot w_i^h(x, y) \cdot w_i^{ang}(x, y)$$

COSTRUZIONE DELLE ANOMALIE

OMOGENEIZZAZIONE DELLE SERIE AVENTI SUFFICIENTE ESTENSIONE TEMPORALE

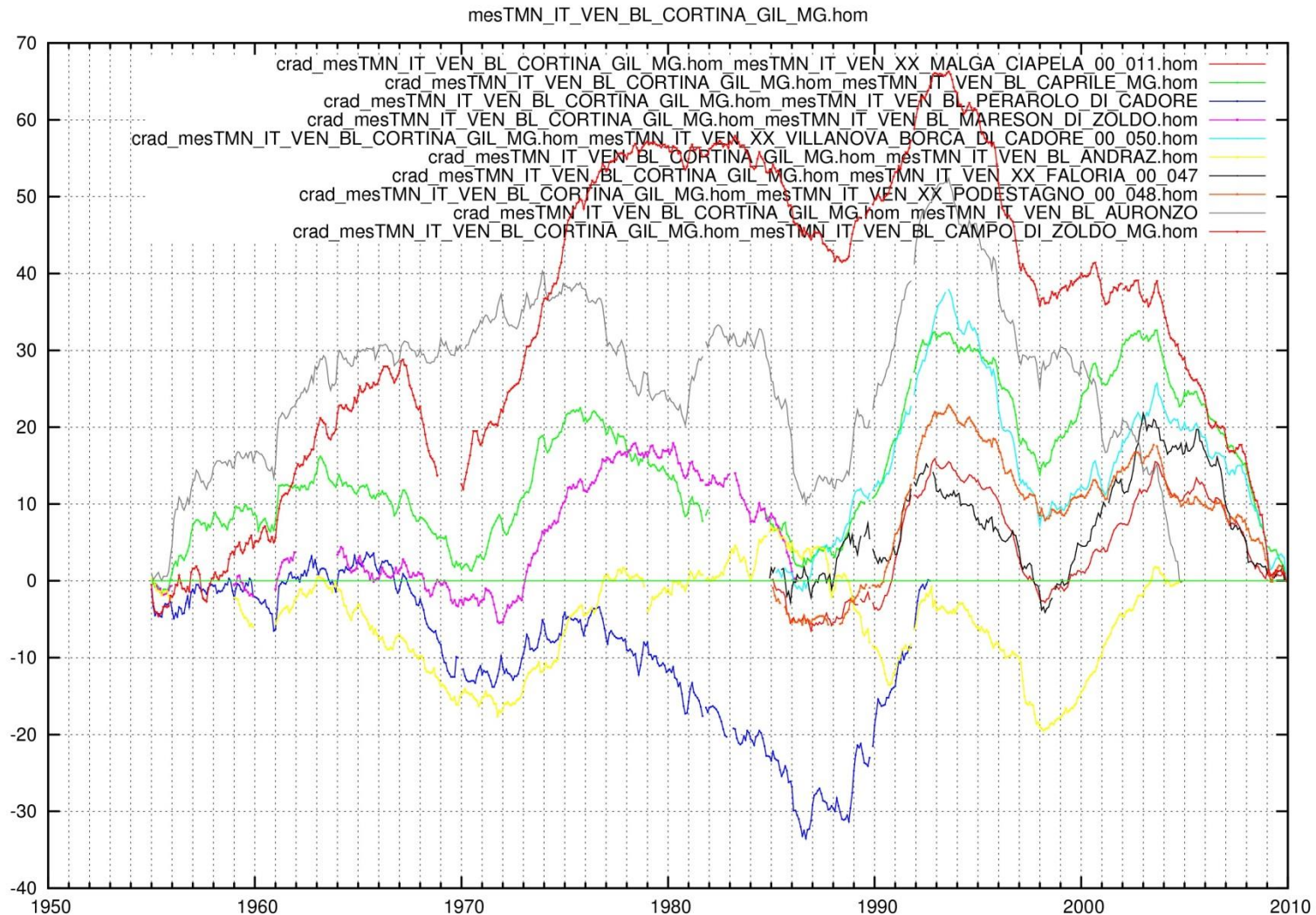
CORTINA MERGING TRA CORTINA (1951-1992) E CORTINA GIL (1993-2009)



COSTRUZIONE DELLE ANOMALIE

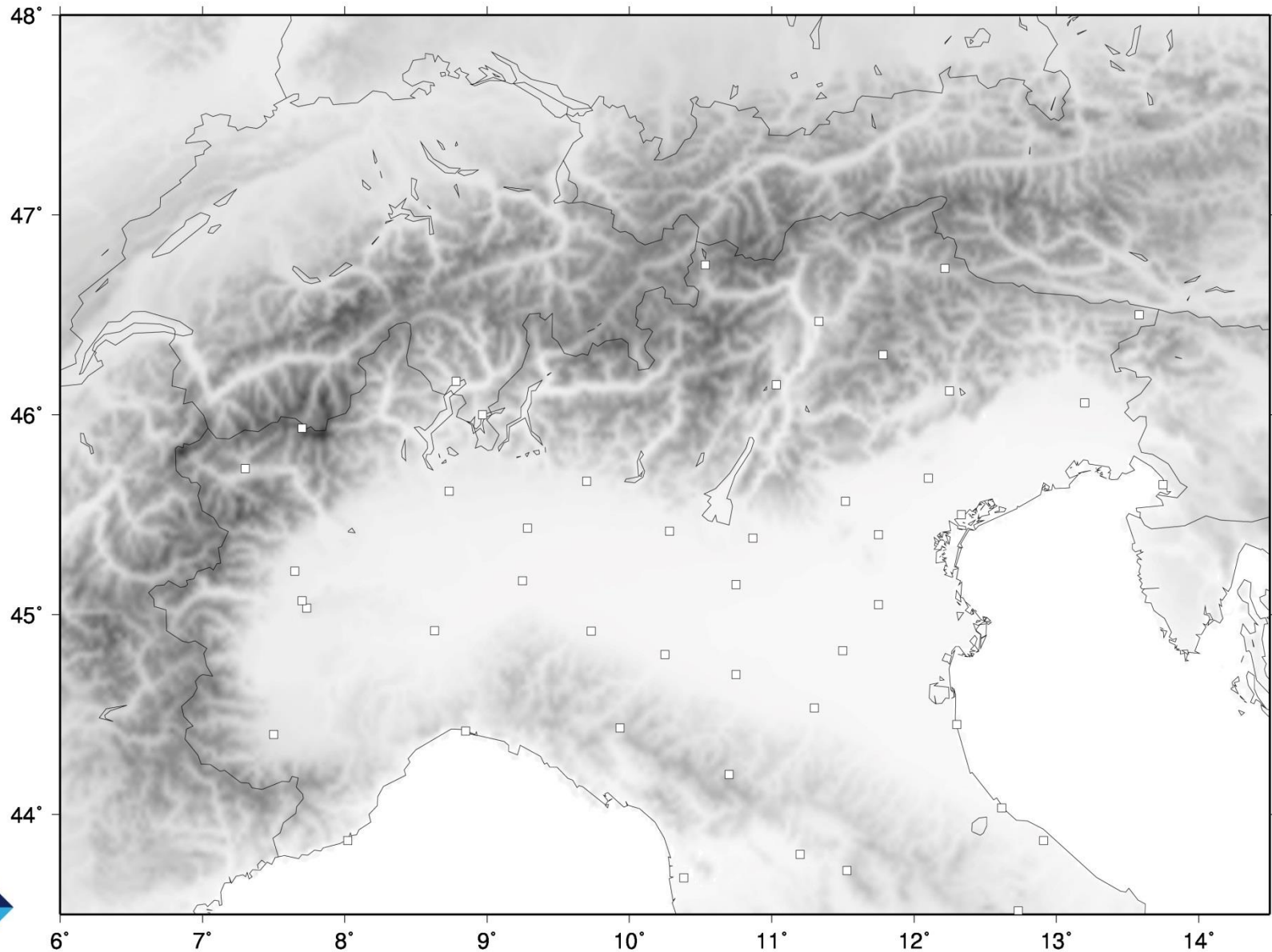
OMOGENEIZZAZIONE DELLE SERIE AVENTI SUFFICIENTE ESTENSIONE TEMPORALE

CORTINA



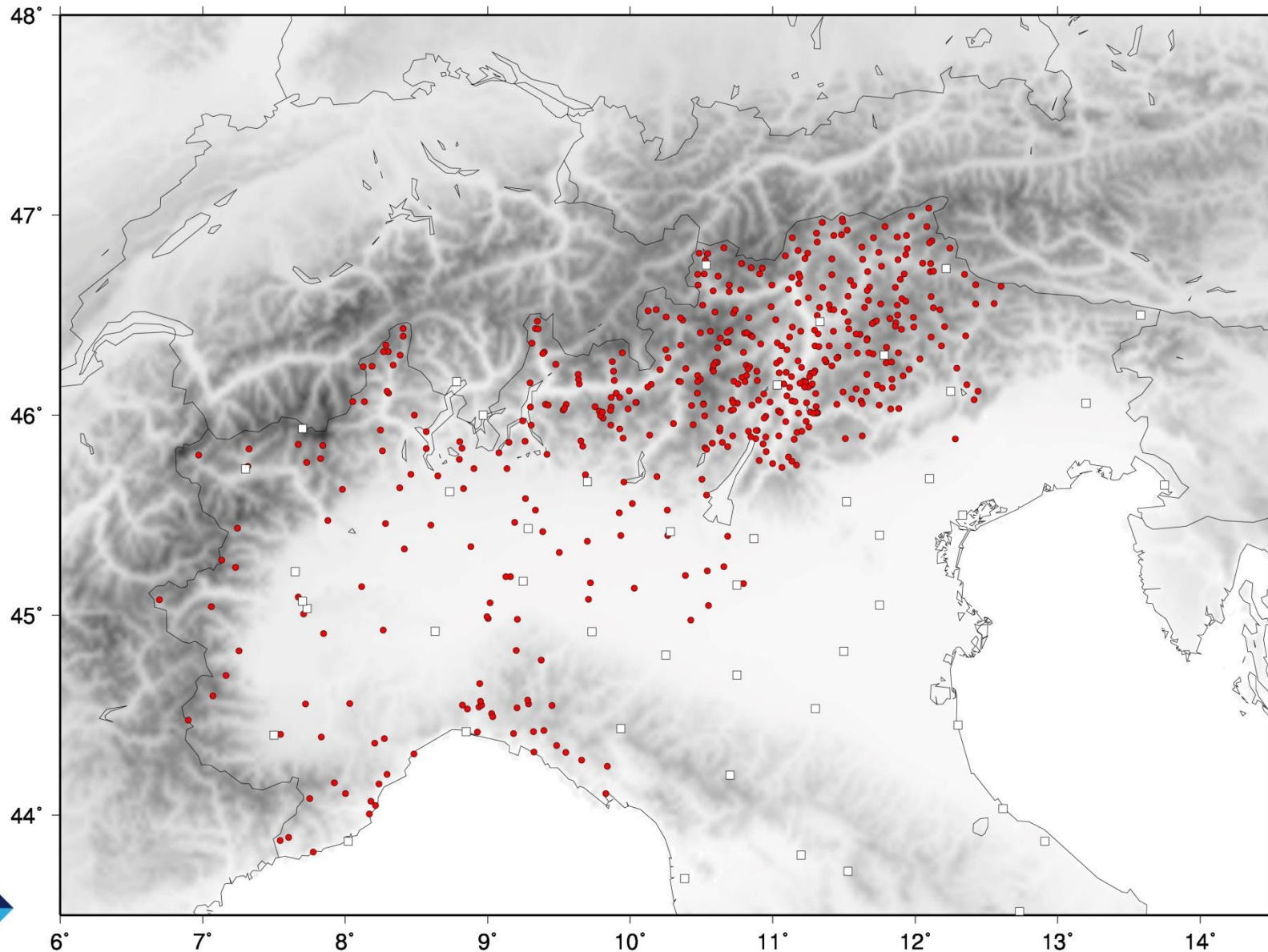
I DATI PER LA COSTRUZIONE DELLE ANOMALIE

TEMPERATURE (disponibilità prima di NextData)



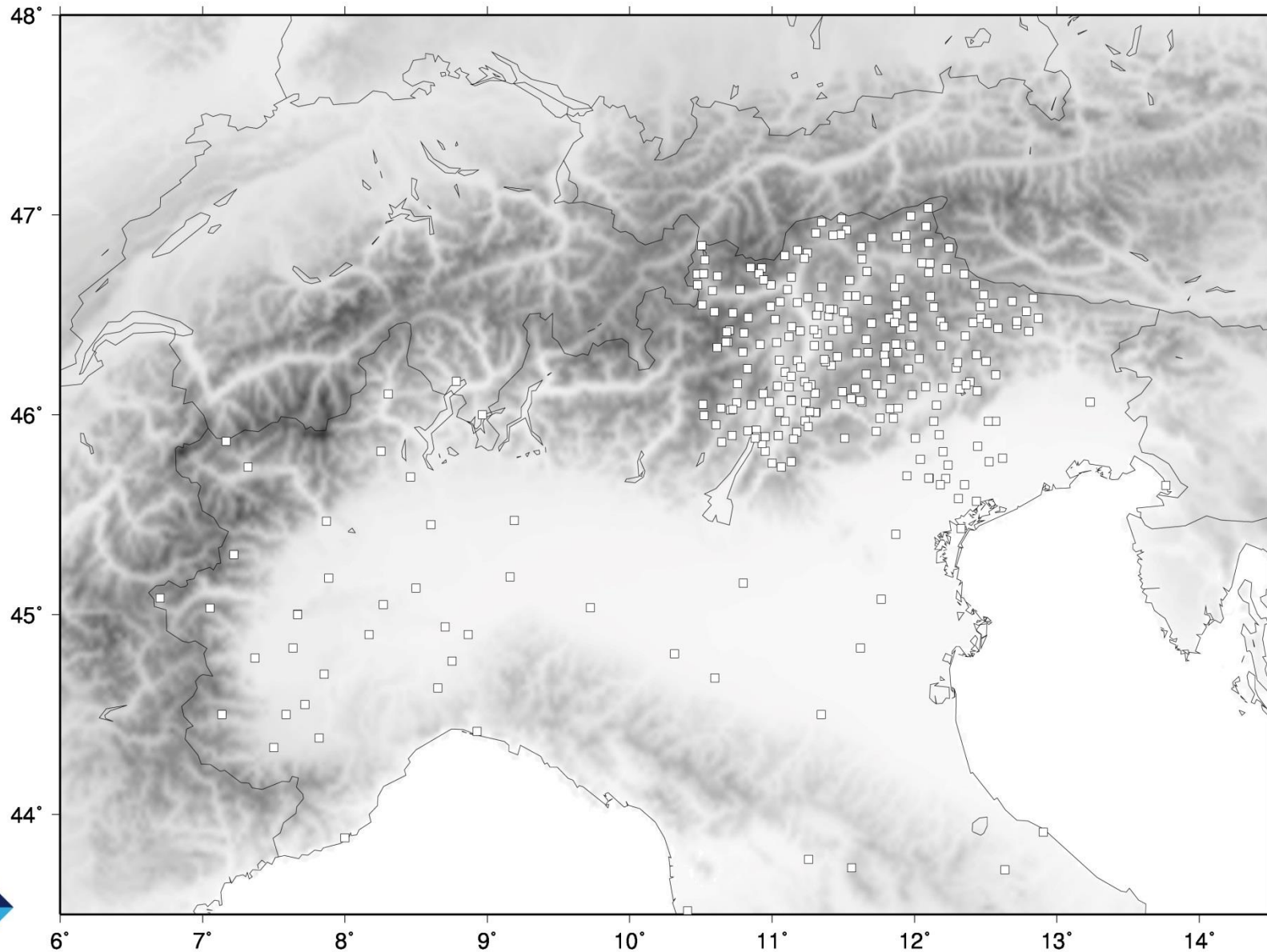
I DATI PER LA COSTRUZIONE DELLE ANOMALIE

TEMPERATURE (data rescue nell'ambito di NextData)



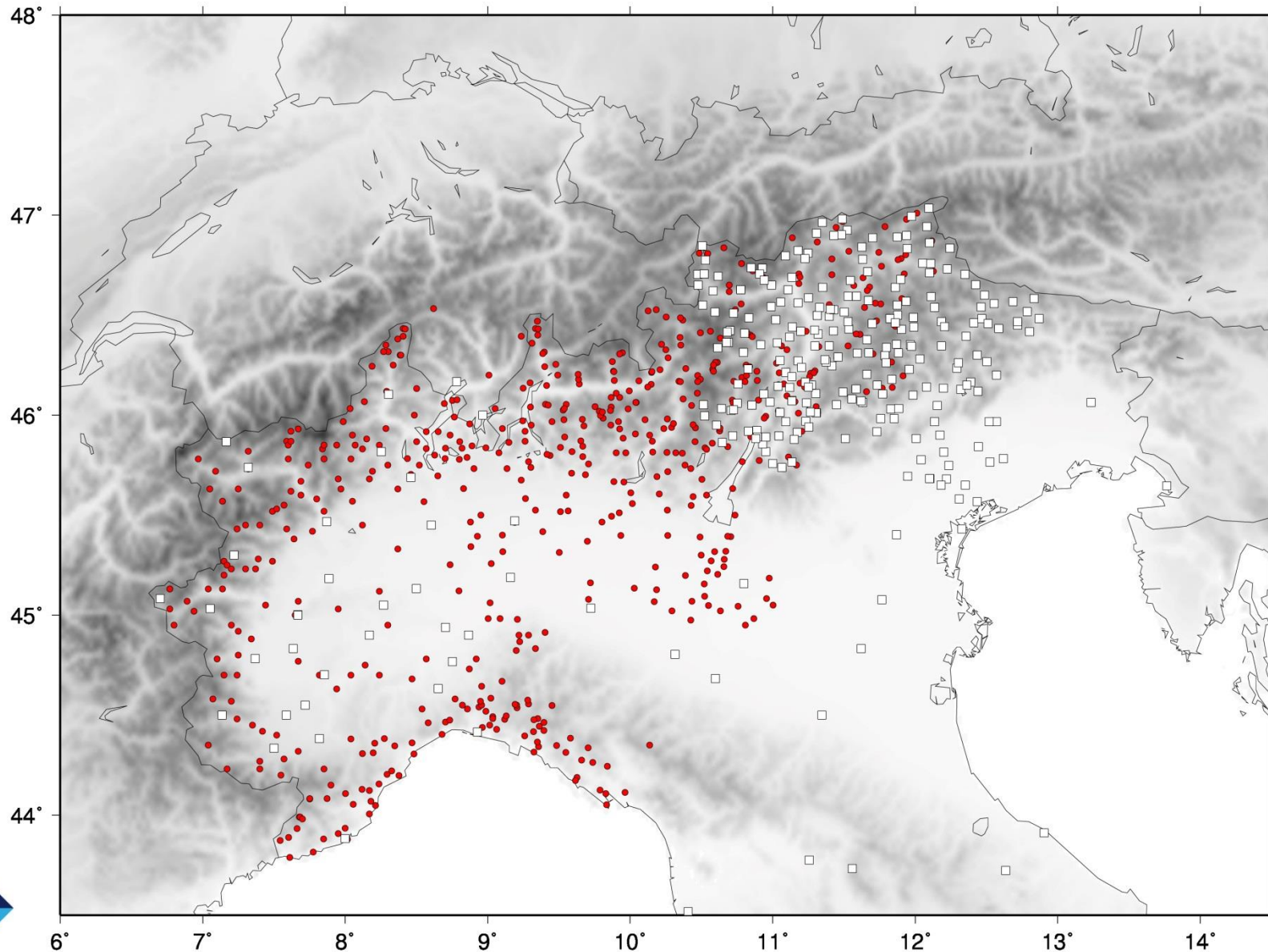
I DATI PER LA COSTRUZIONE DELLE ANOMALIE

PRECIPITAZIONI (disponibilità prima di NextData)



I DATI PER LA COSTRUZIONE DELLE ANOMALIE

PRECIPITAZIONI (data rescue nell'ambito di NextData)



SOVRAPPOSIZIONE CLIMATOLOGIE+ANOMALIE

SOVRAPPOSIZIONE CLIMATOLOGIE+ANOMALIE

Let's show an example of the method. Let's suppose that we have to estimate a secular temperature/precipitation record for the following point:

Latitude: 45.05 N; Longitude: 11.77 E; height: 9 m (i.e. Rovigo).

Step 1)

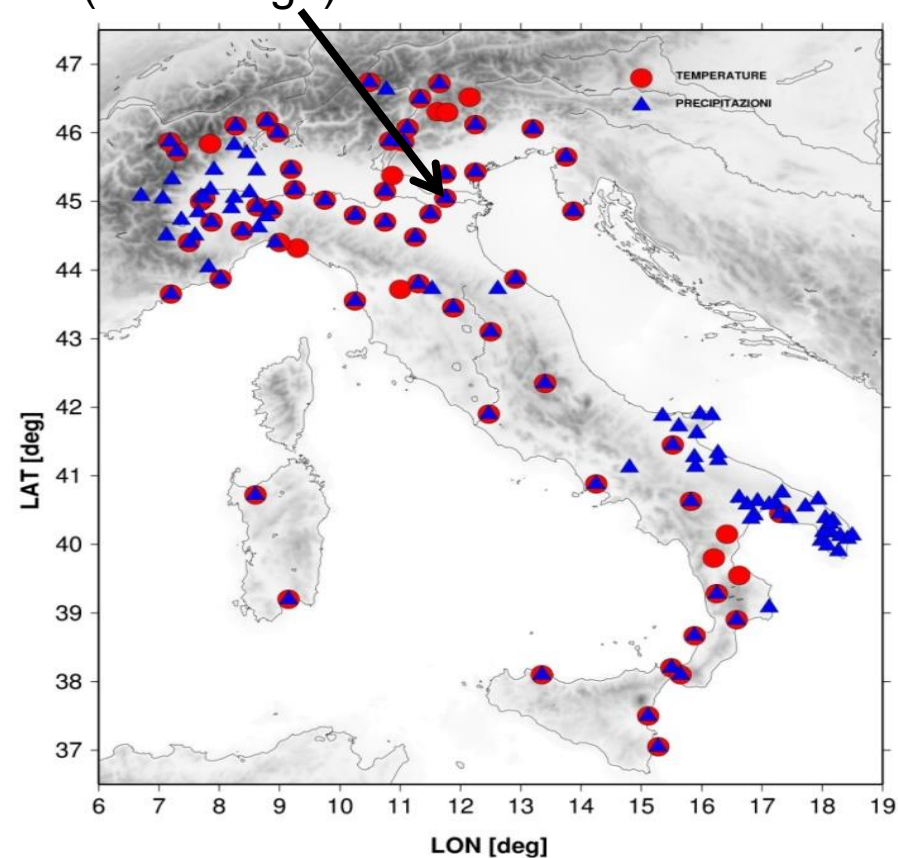
An anomalies **temperature/precipitation** series is calculated for the grid point by means of the neighboring stations (excluding Rovigo from the dataset!!)

Step 2)

The 1961-1990 monthly normals are estimated by means of the **variable vs elevation model** (excluding Rovigo from the dataset!!).

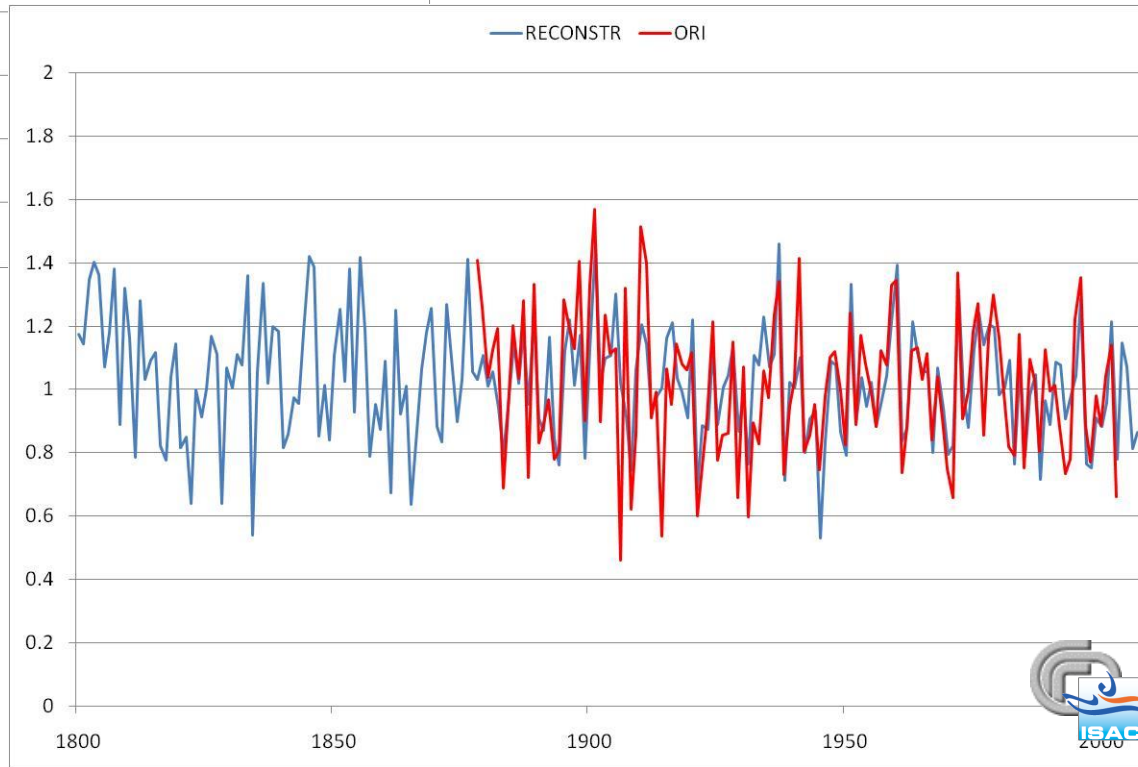
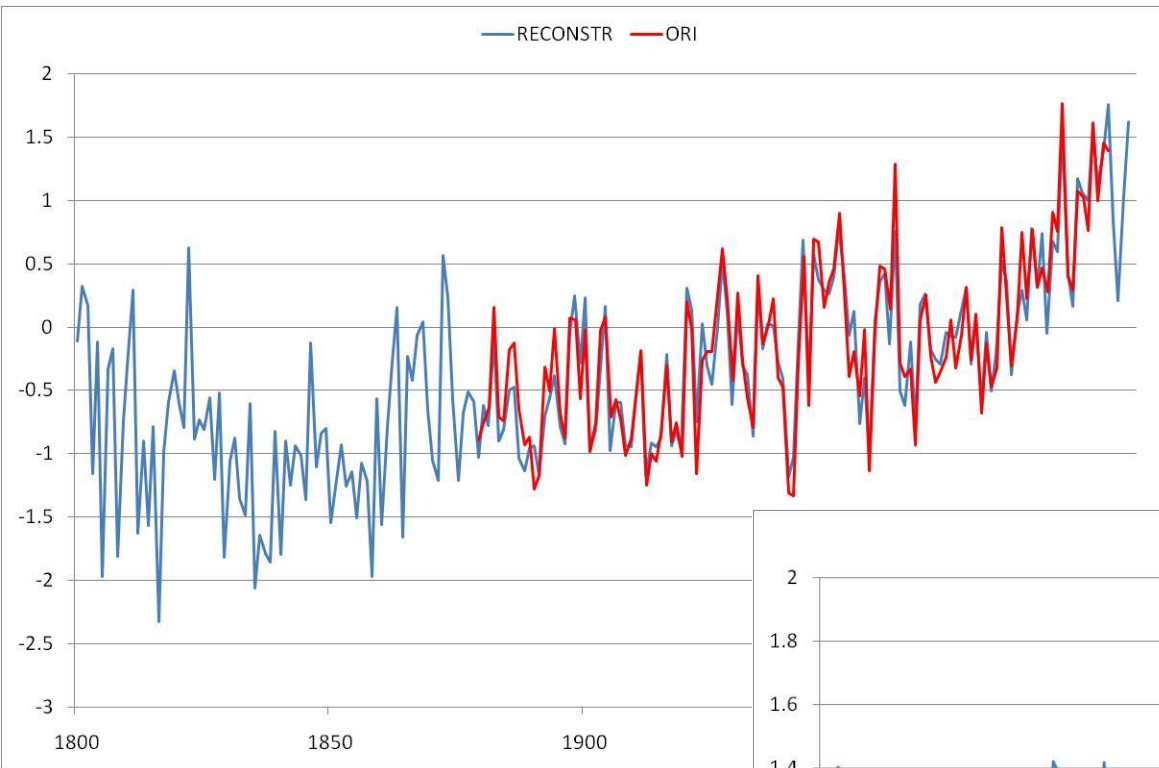
Step 3)

The 1961-1990 monthly normals are **added** to each corresponding monthly value of the anomalies series to finally get the absolute value series



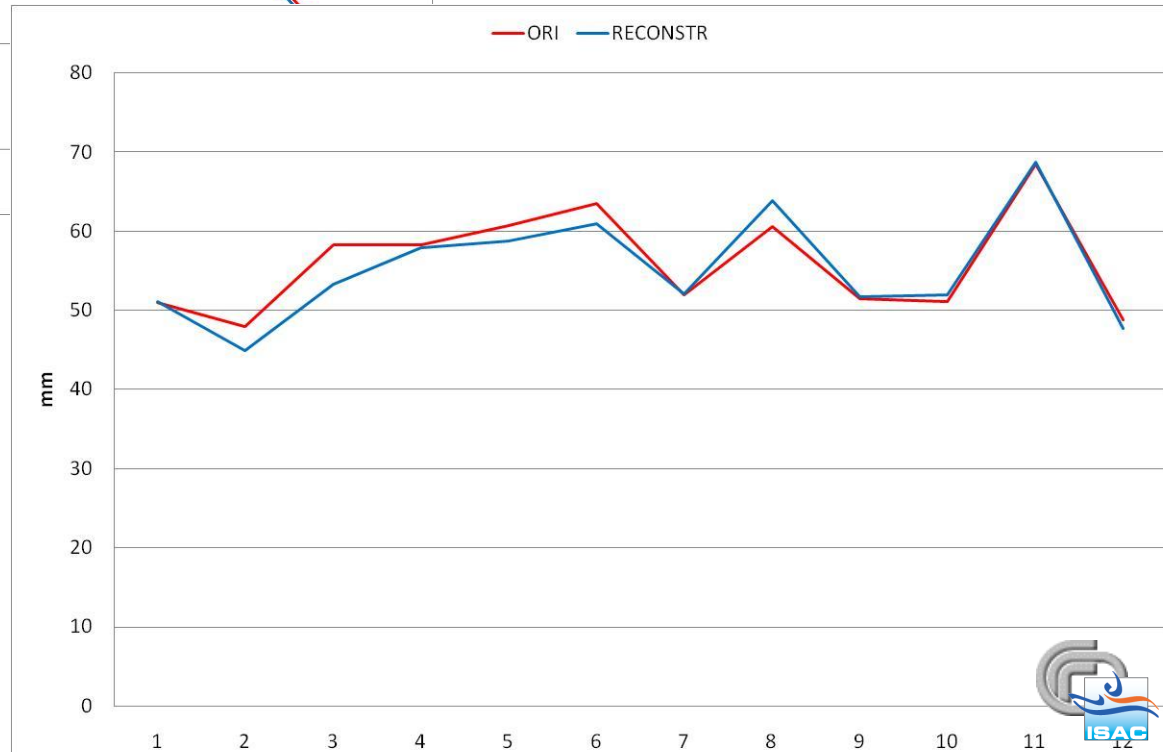
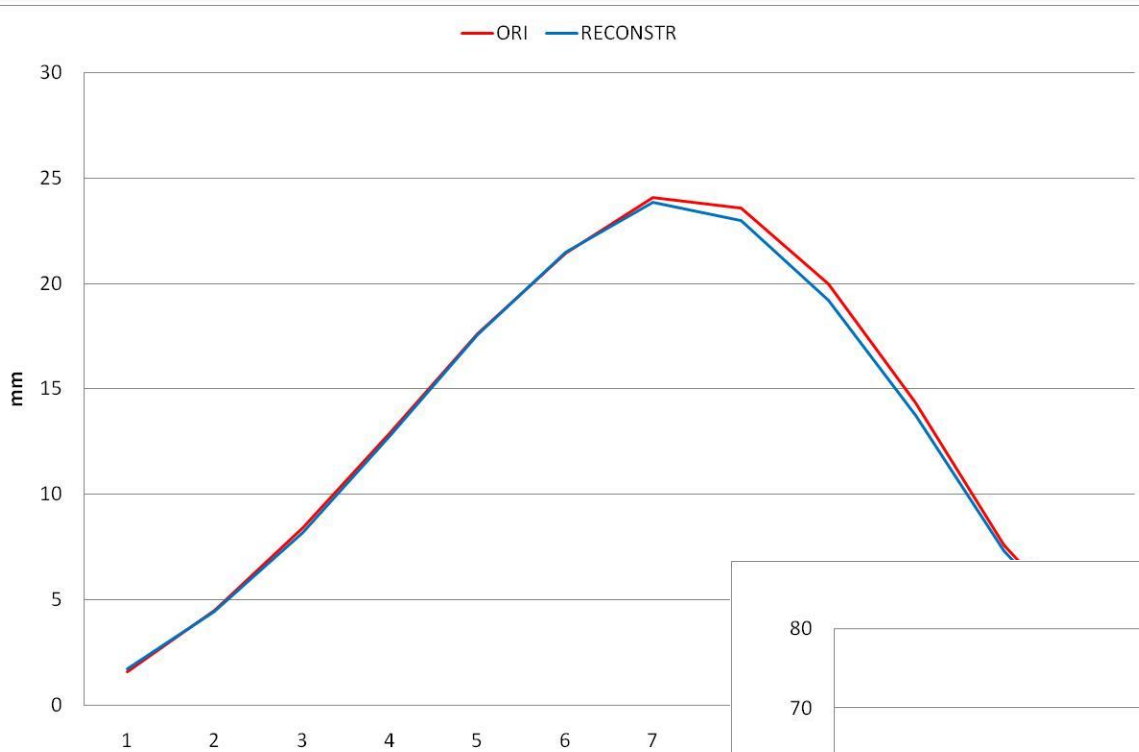
ALCUNI RISULTATI

YEAR ANOMALIES



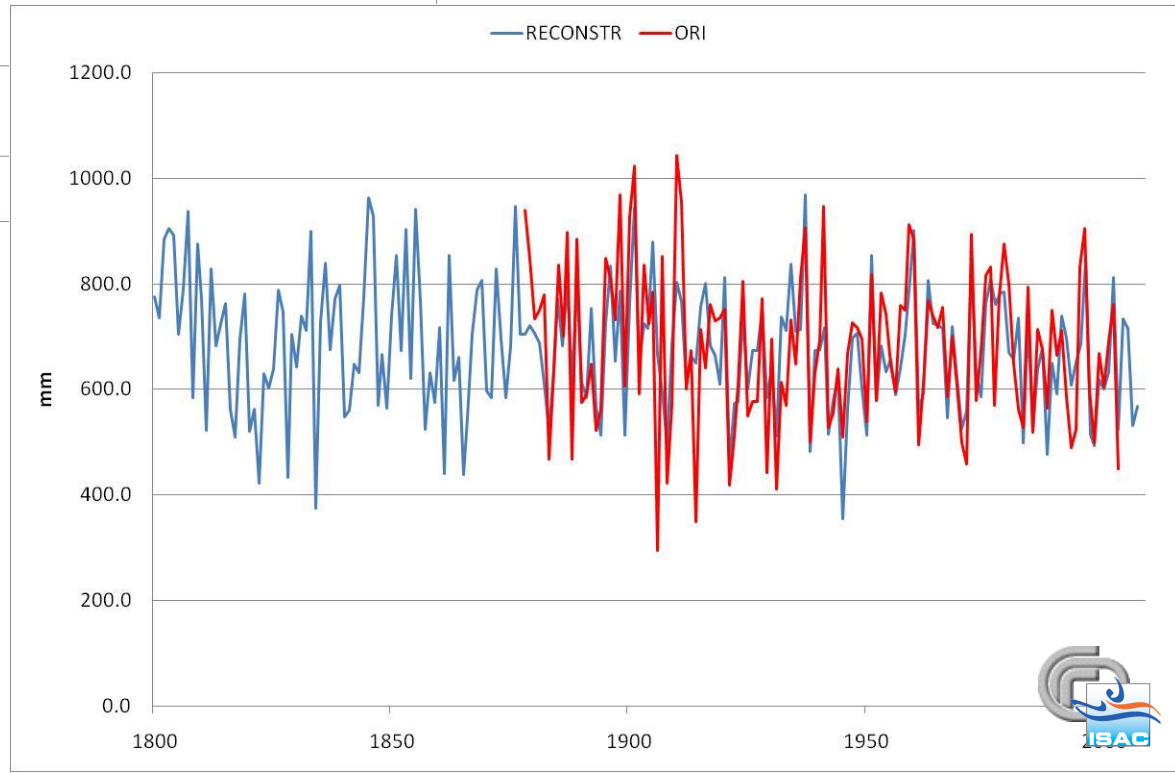
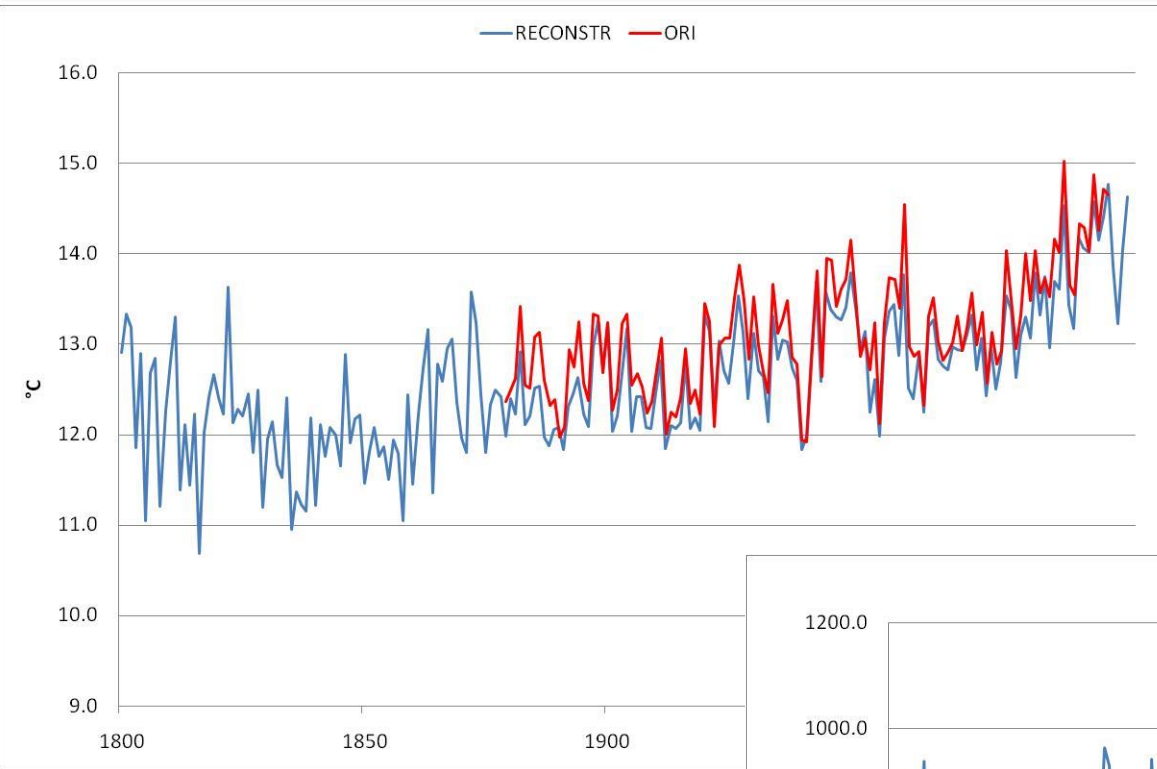
SOVRAPPOSIZIONE CLIMATOLOGIE+ANOMALIE

CLIMATOLOGIES



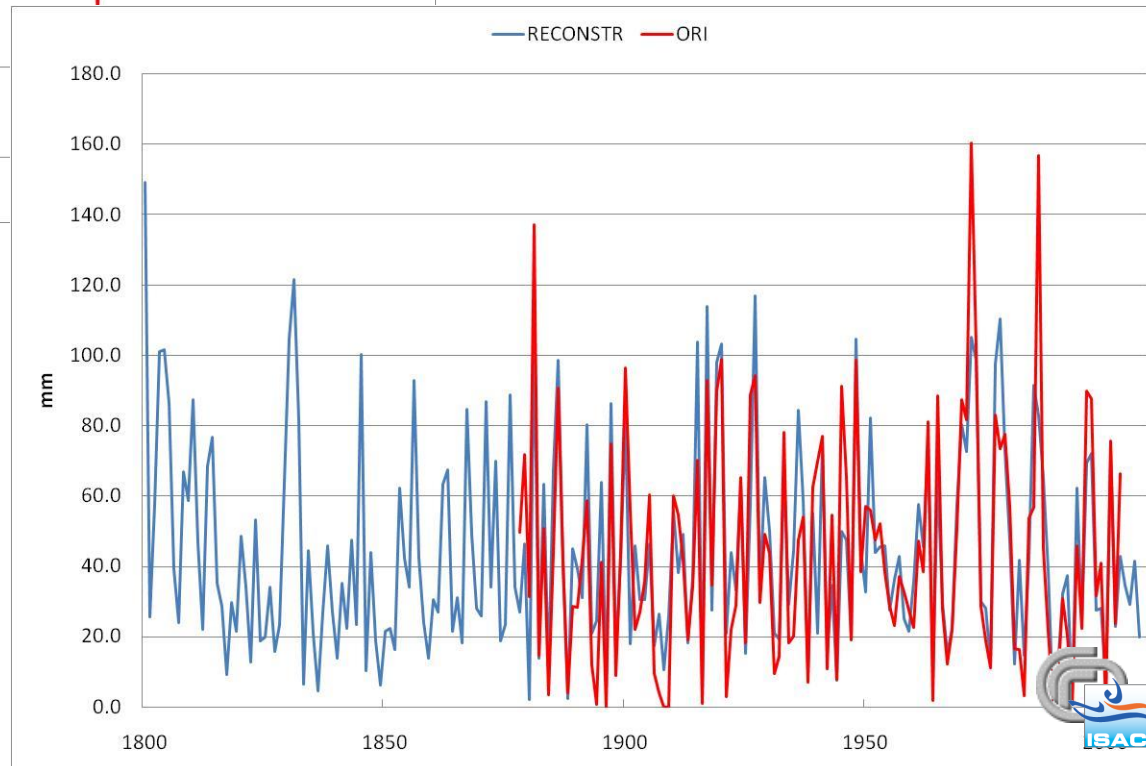
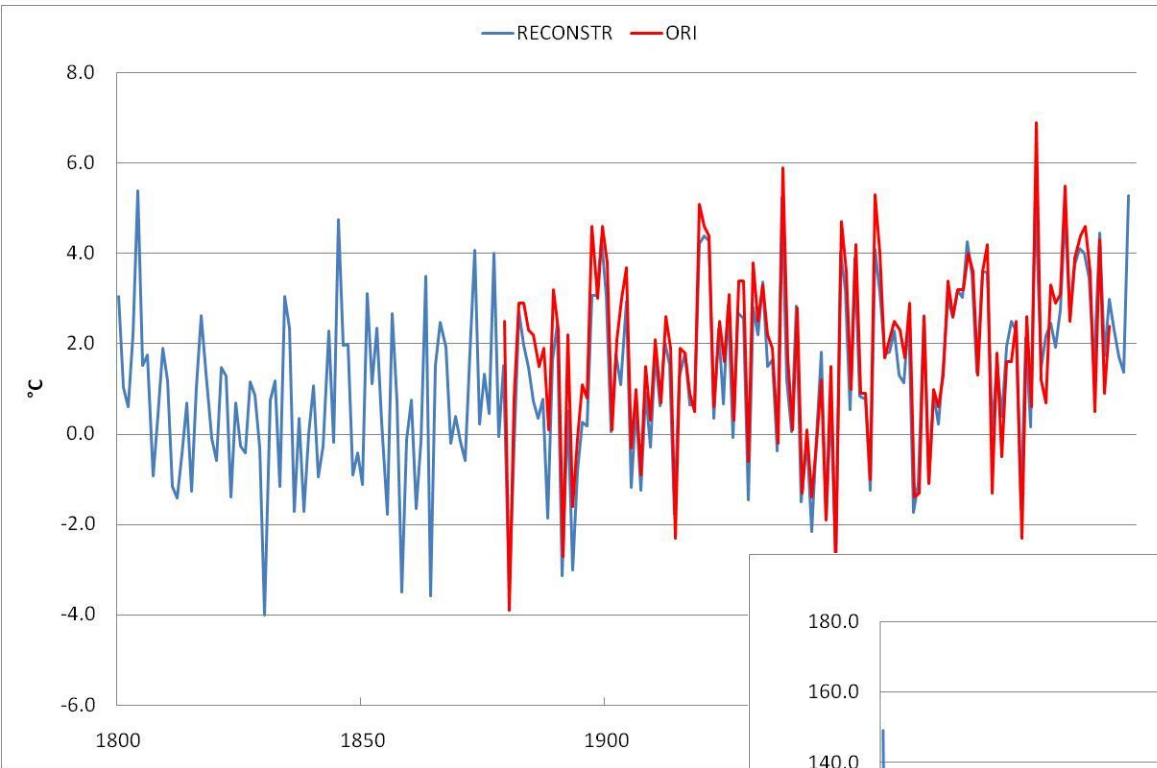
SOVRAPPOSIZIONE CLIMATOLOGIE+ANOMALIE

YEAR
ABSOLUTE VALUES



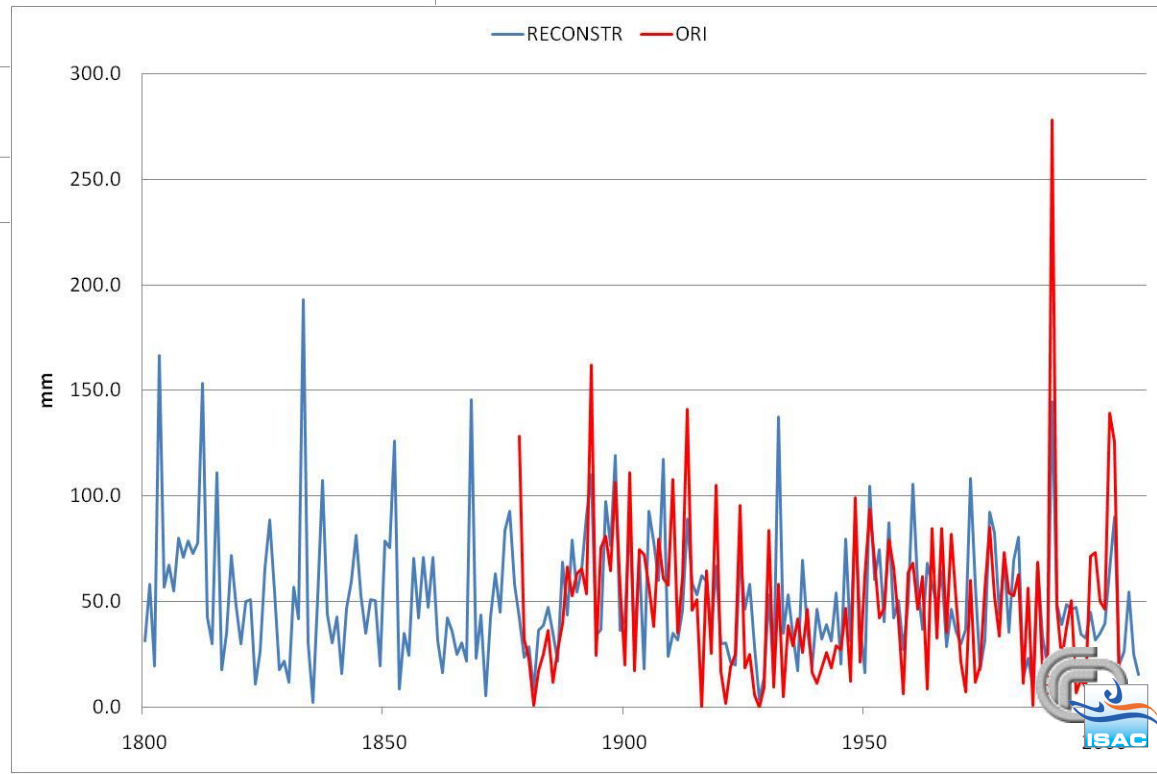
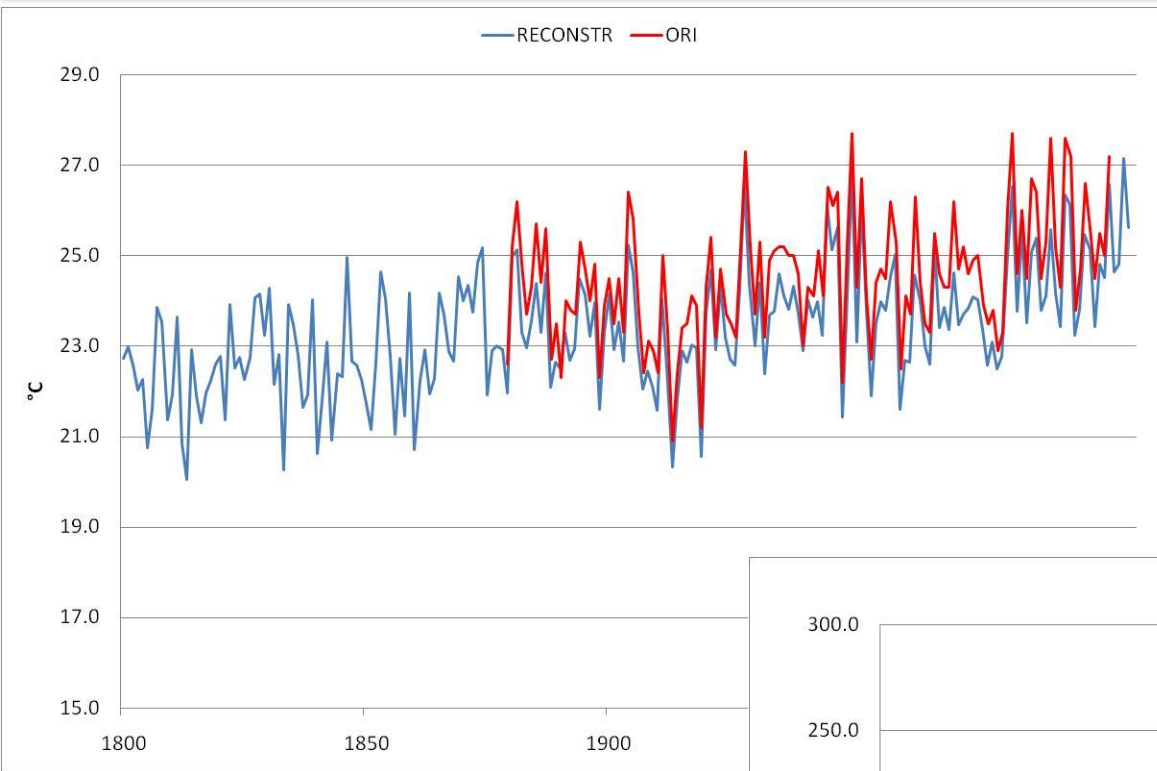
SOVRAPPOSIZIONE CLIMATOLOGIE+ANOMALIE

JANUARY ABSOLUTE VALUES



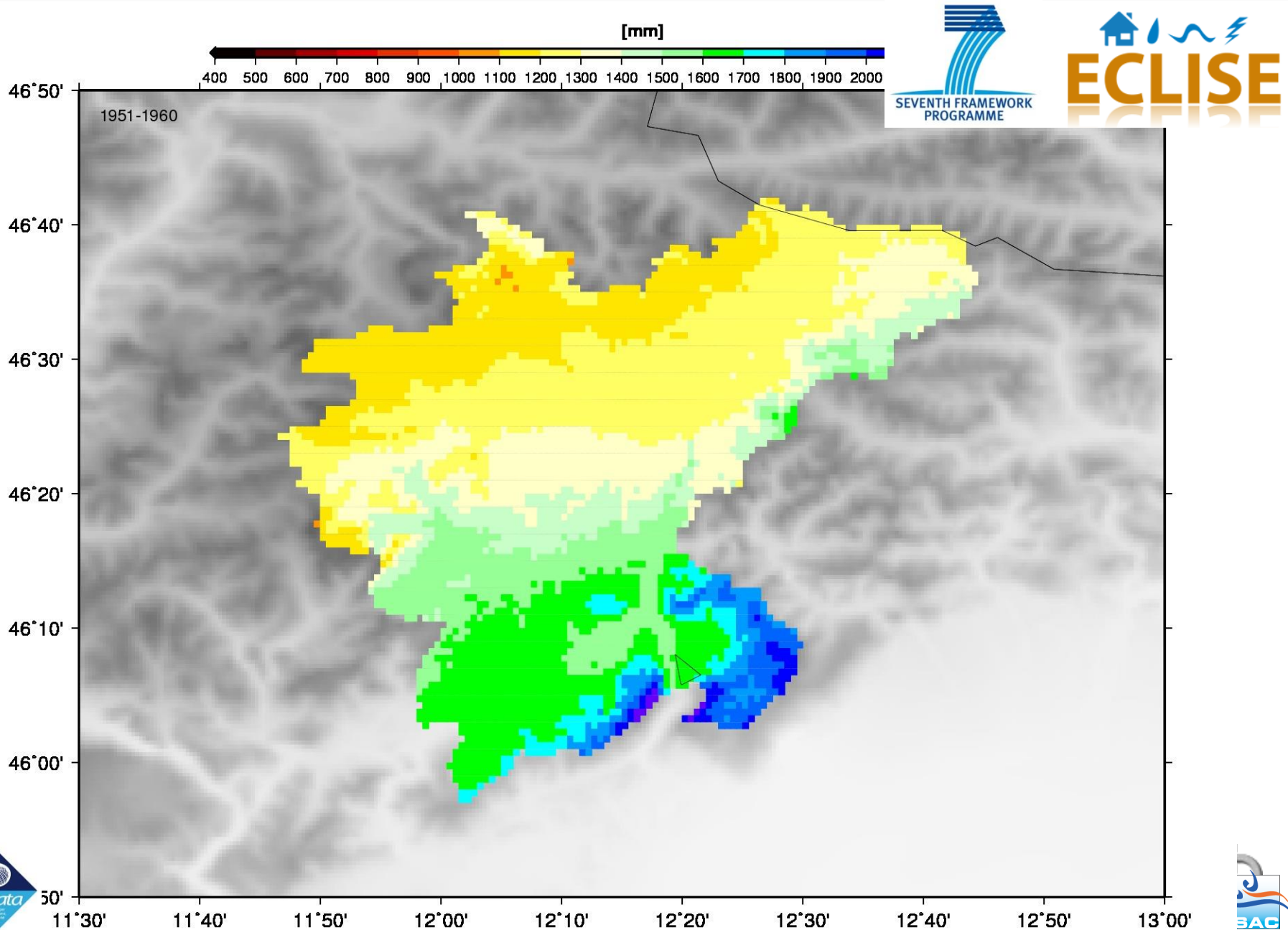
SOVRAPPOSIZIONE CLIMATOLOGIE+ANOMALIE

JULY ABSOLUTE VALUES

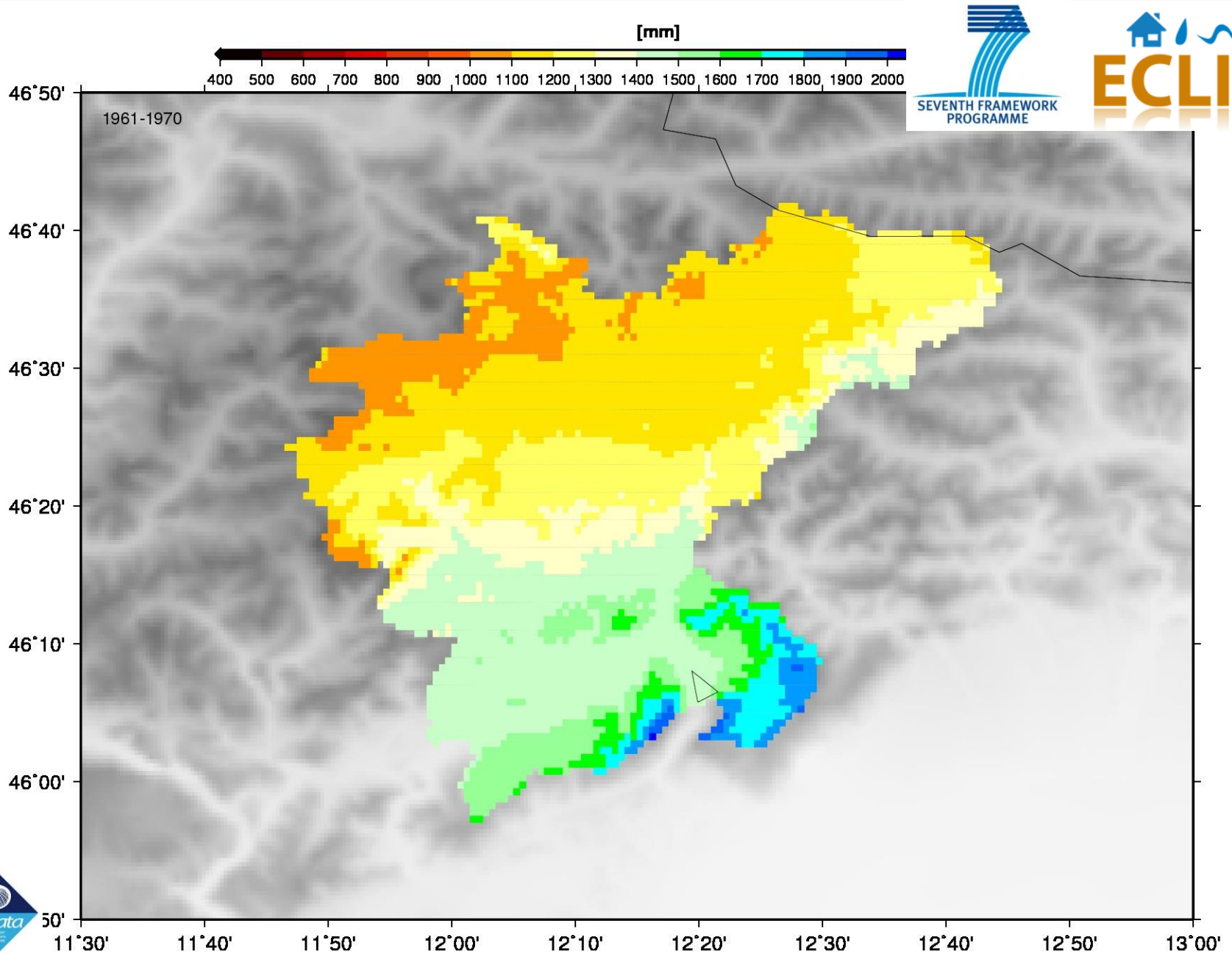


UN ESEMPIO DAL PROGETTO ECLISE

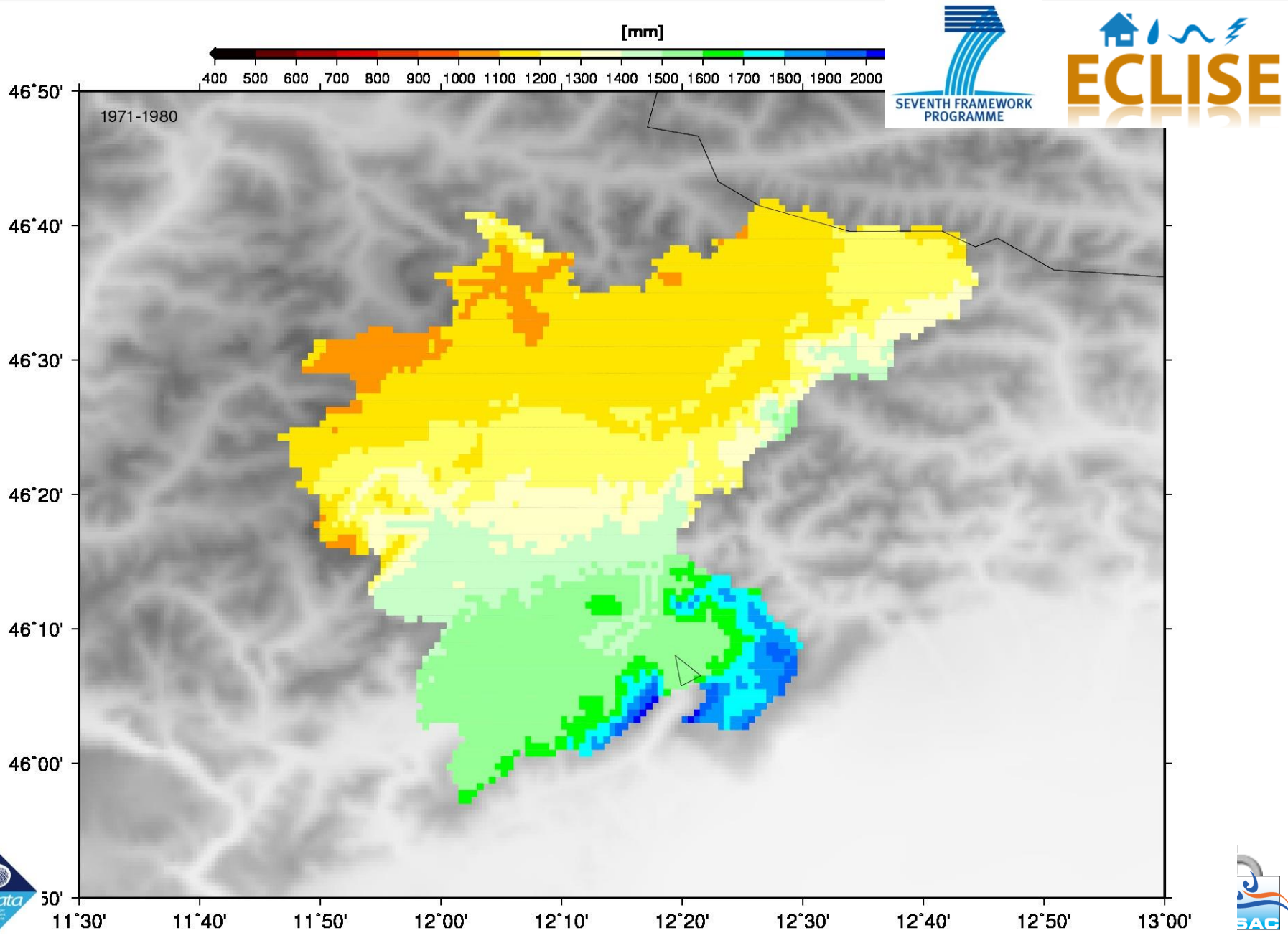
1951-1960 ANNUAL PRECIPITATION



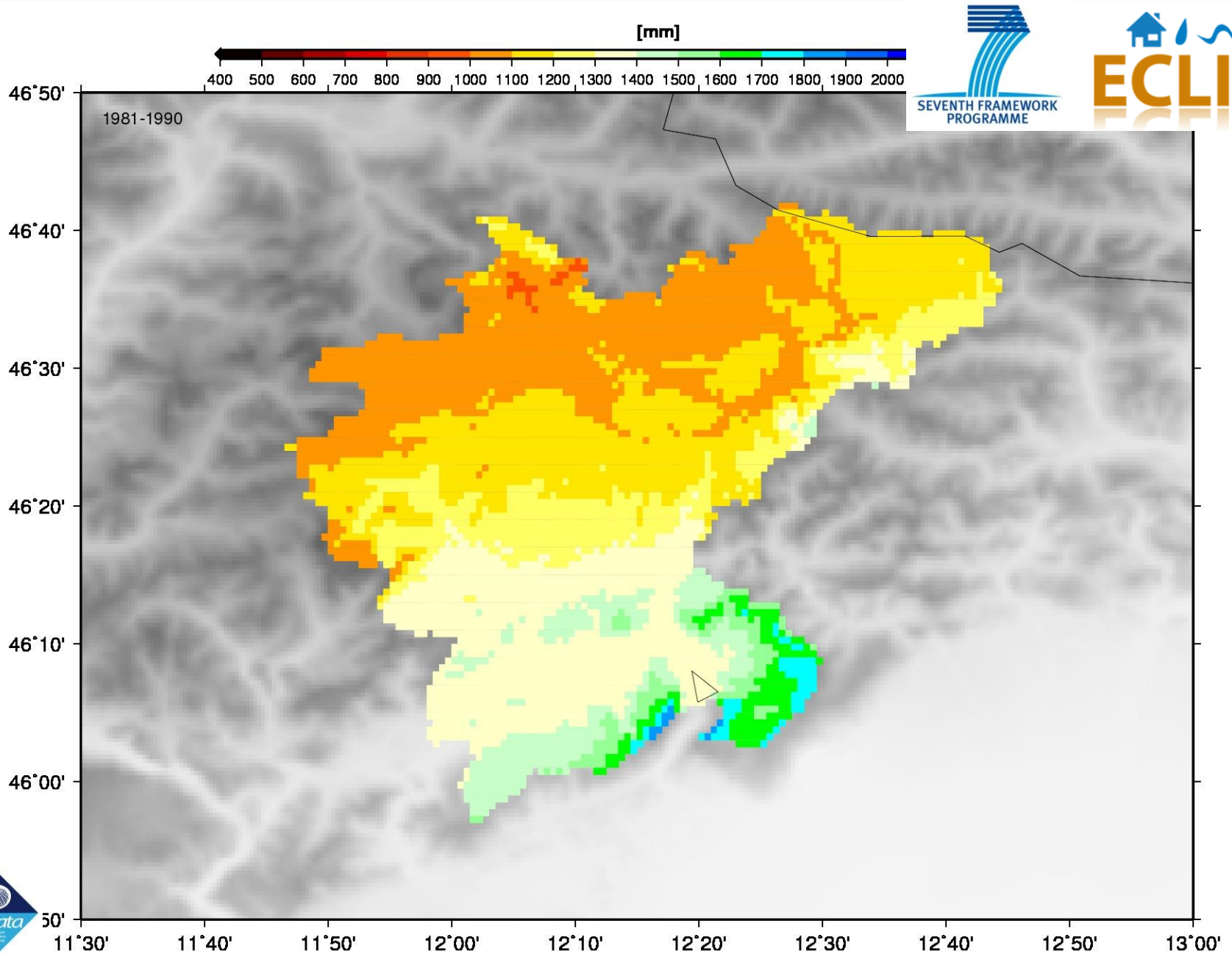
1961-1970 ANNUAL PRECIPITATION



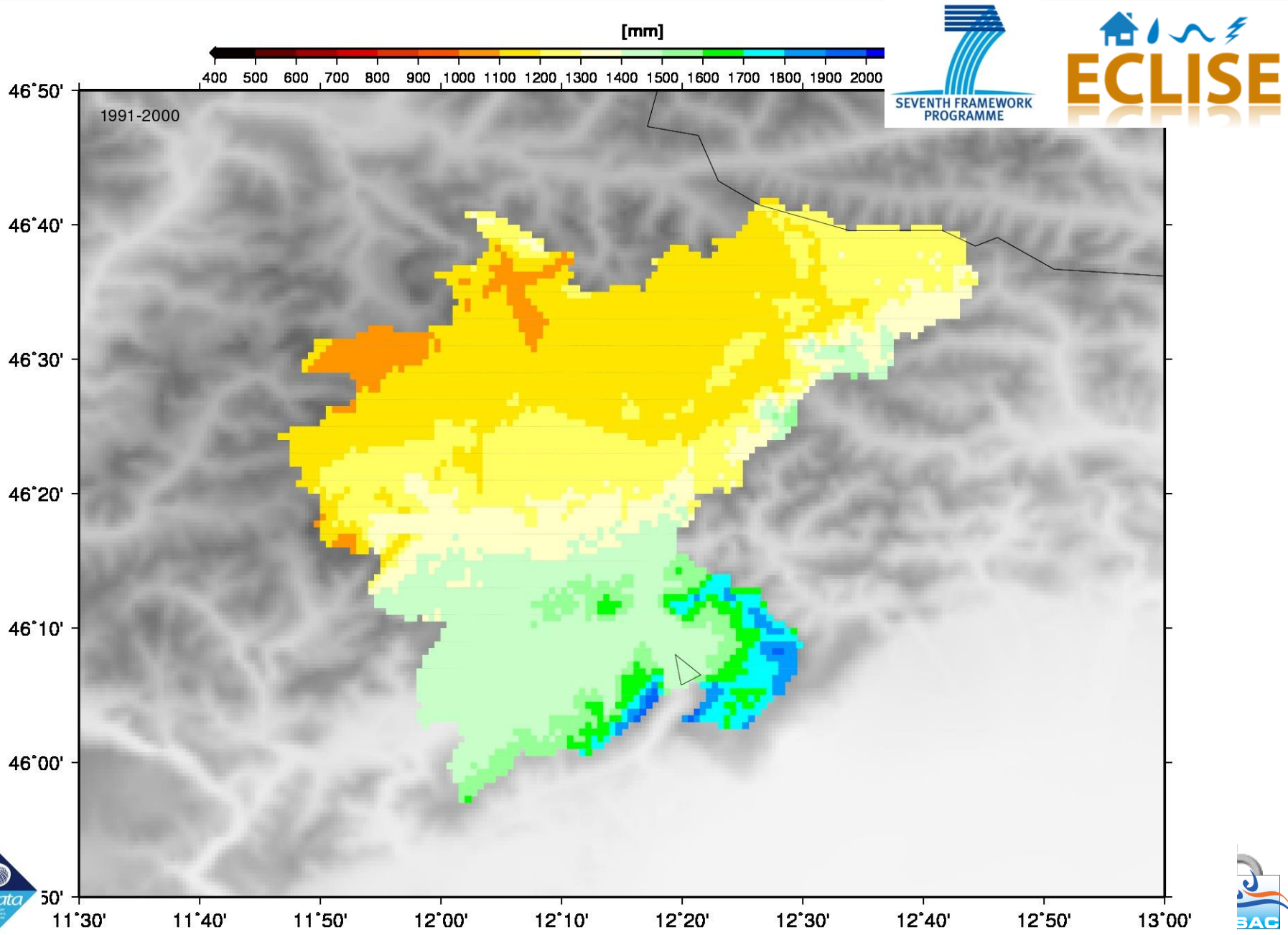
1971-1980 ANNUAL PRECIPITATION



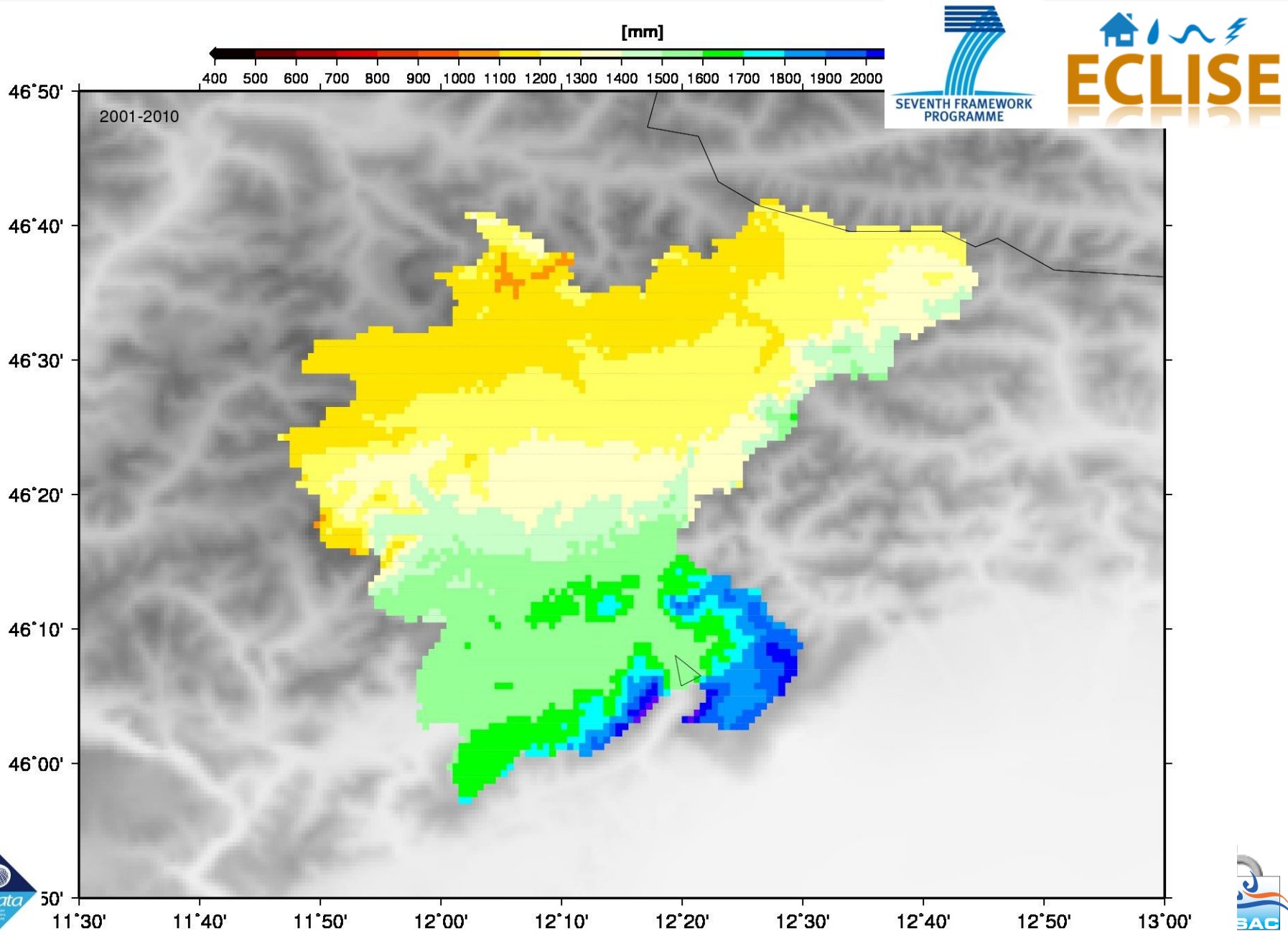
1981-1990 ANNUAL PRECIPITATION



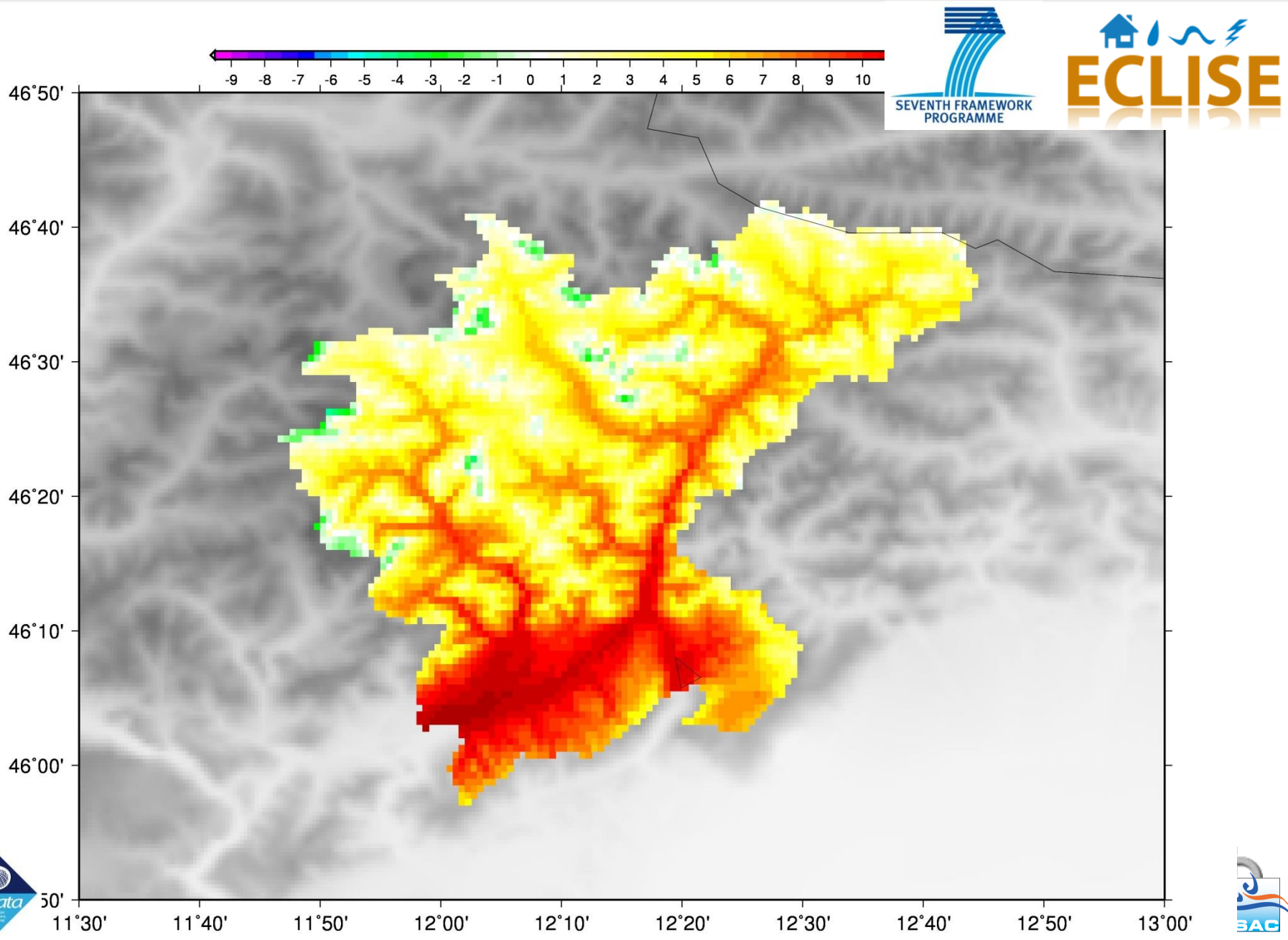
1991-2000 ANNUAL PRECIPITATION



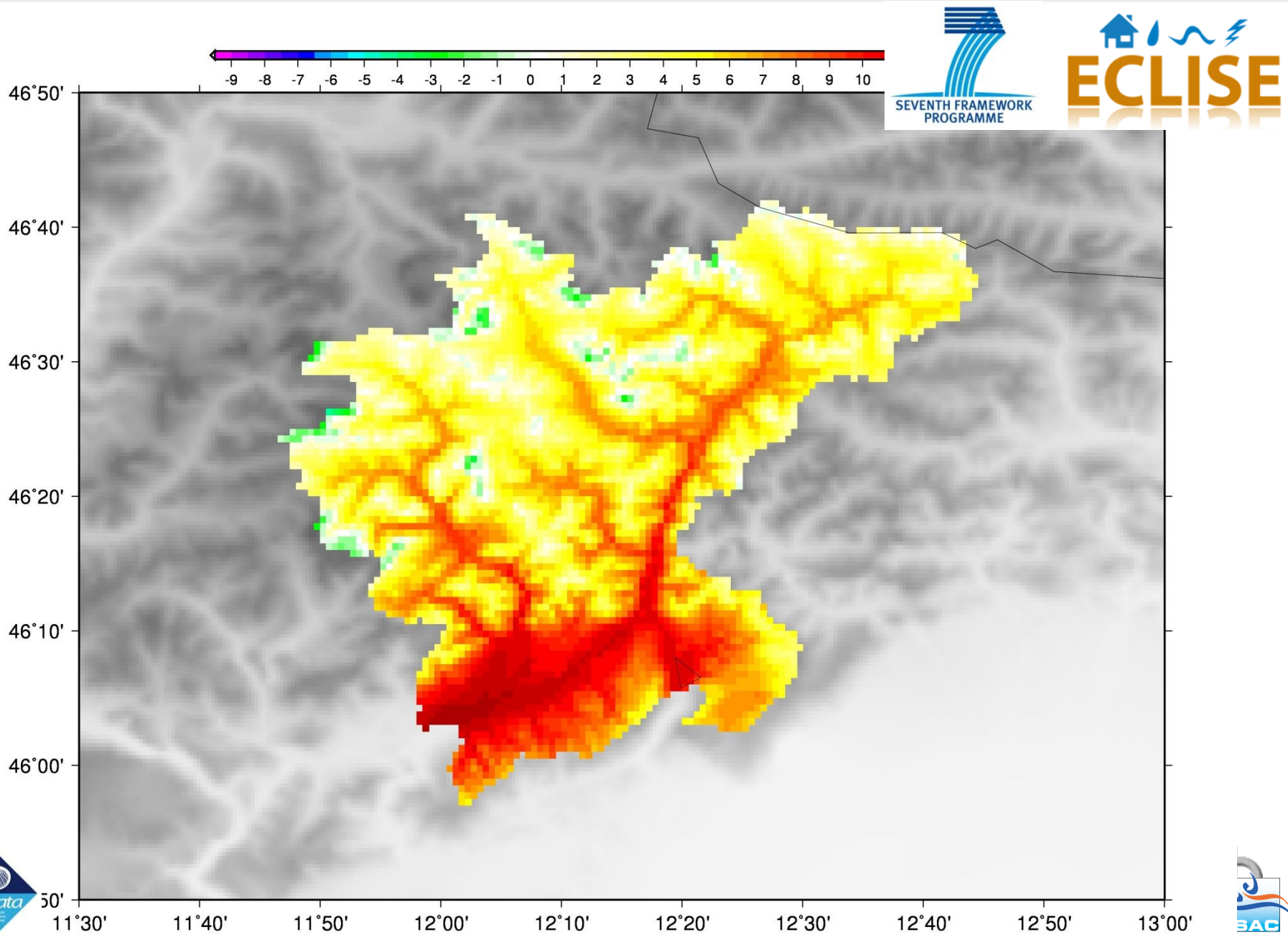
2001-2010 ANNUAL PRECIPITATION



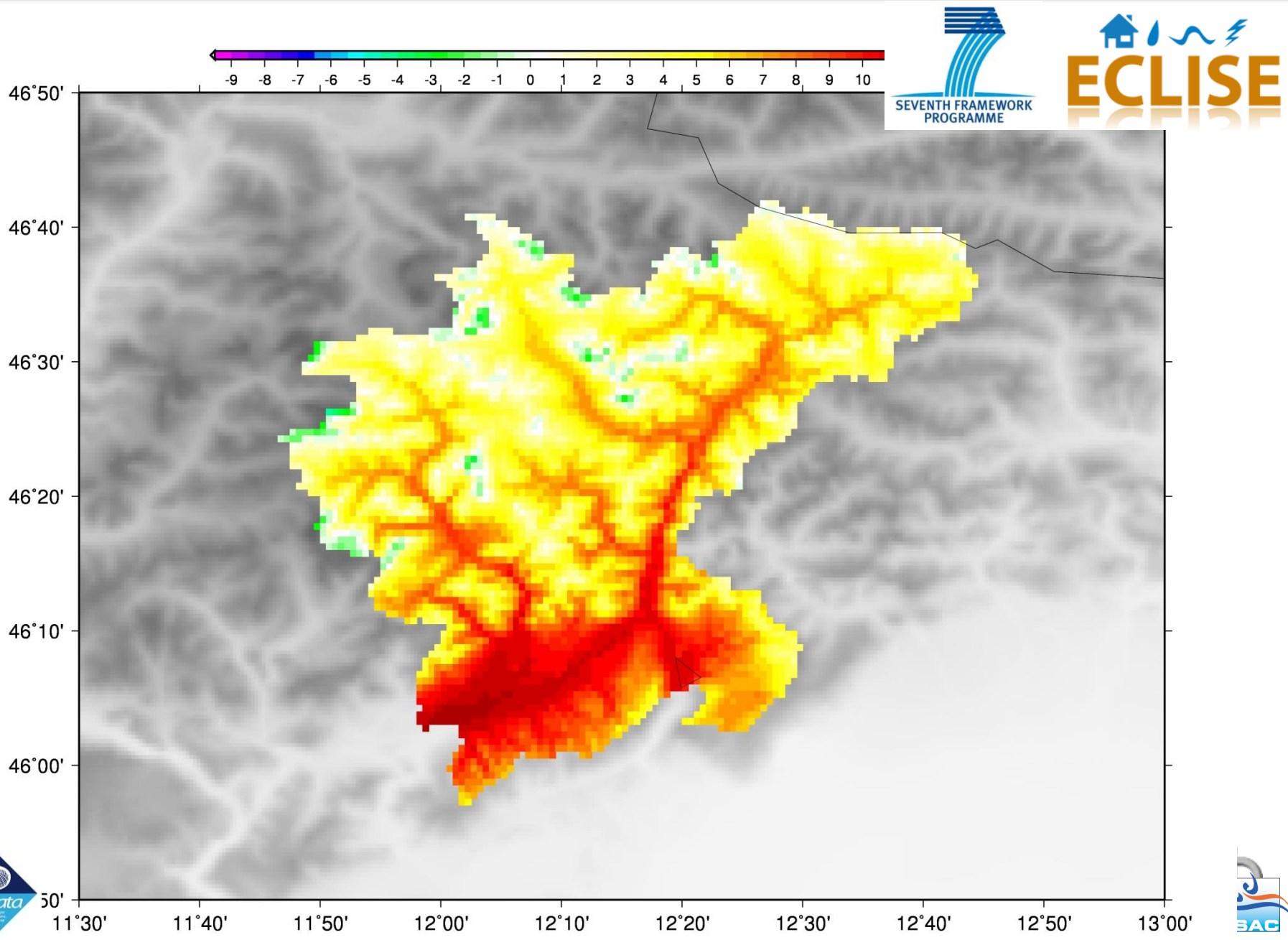
1951-1960 MEAN ANNUAL TEMPERATURE



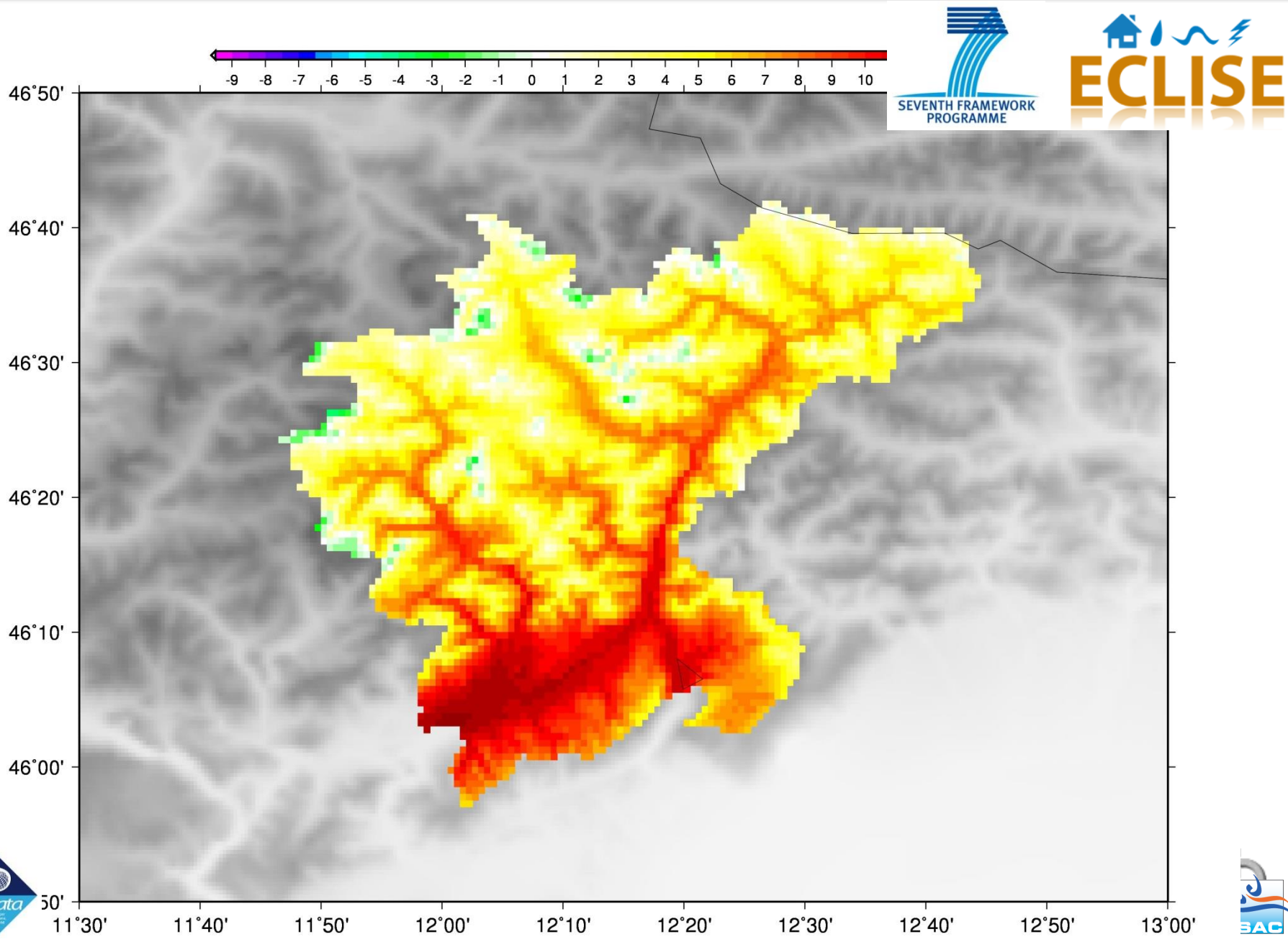
1961-1970 MEAN ANNUAL TEMPERATURE



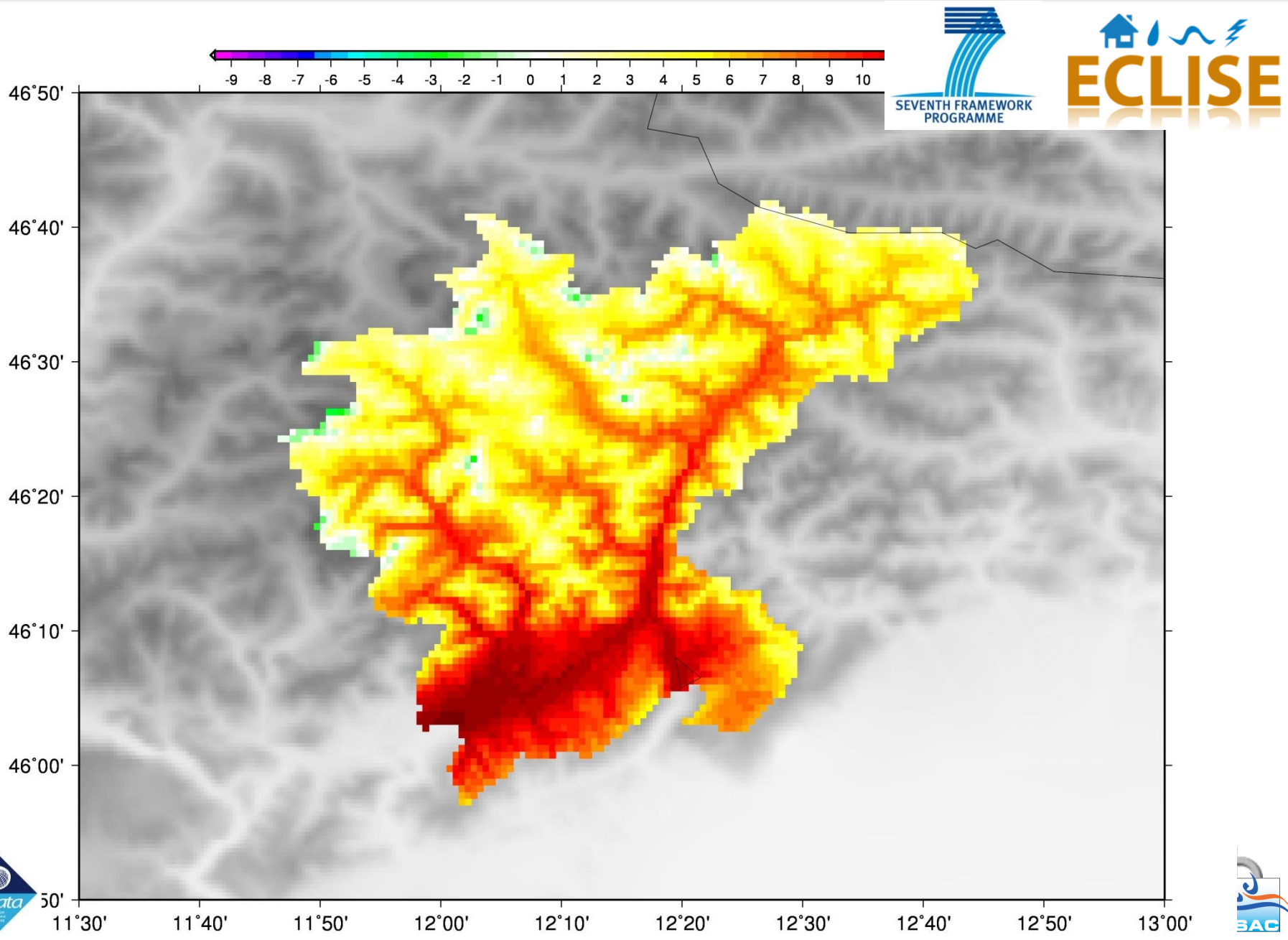
1971-1980 MEAN ANNUAL TEMPERATURE



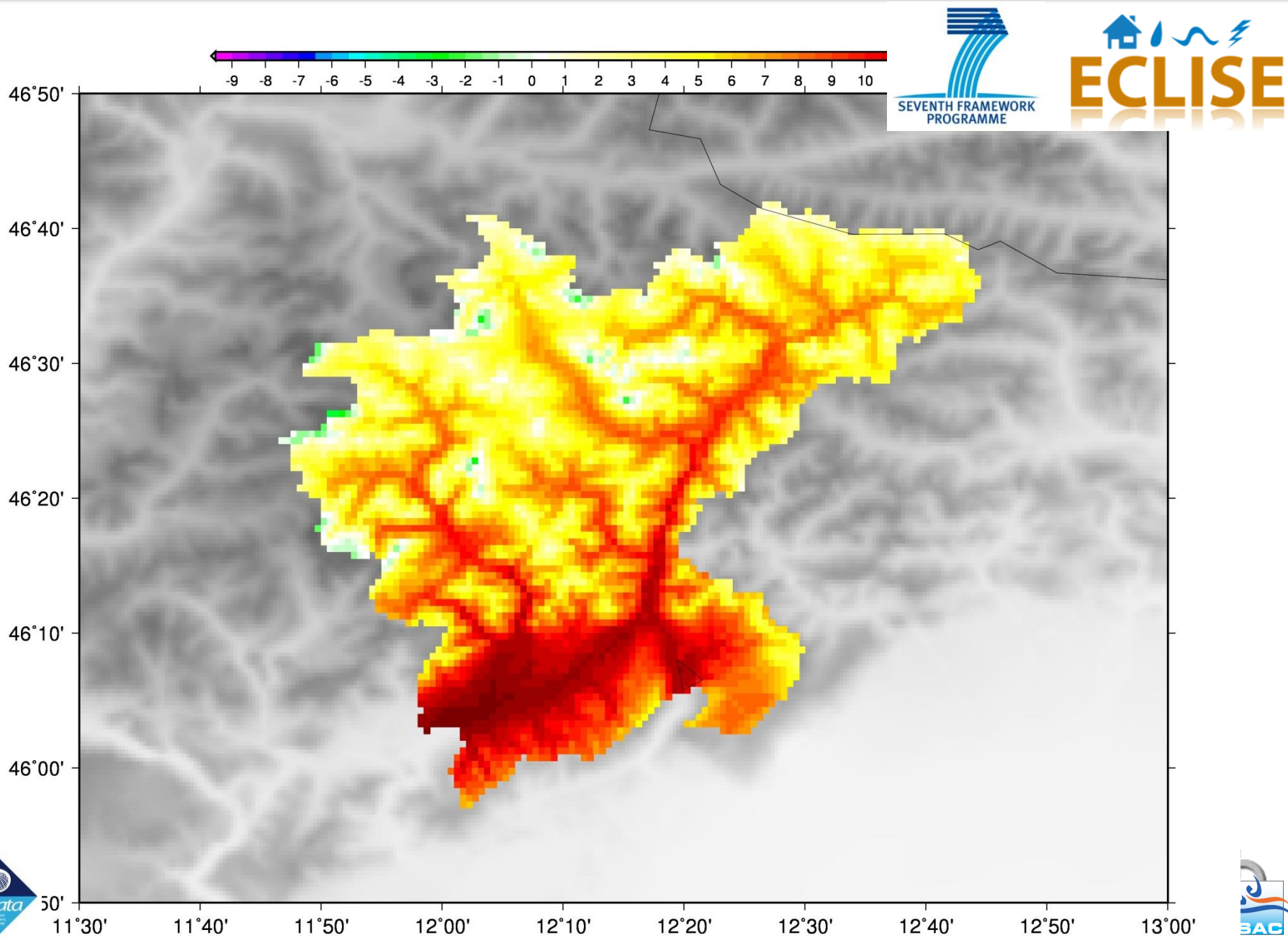
1981-1990 MEAN ANNUAL TEMPERATURE



1991-2000 MEAN ANNUAL TEMPERATURE



2001-2010 MEAN ANNUAL TEMPERATURE



COMPARISON WITH SNOW ACCUMULATION

Snow water equivalent vs precipitation estimation

Sono stati estratti i dati relativi ai punti di monitoraggio di altezza e densità del manto nevoso, relativi al bacino del fiume Piave, relativi agli anni nei quali sono state effettuate in passato misure di altezza e densità del manto nevoso per le due campagne del 1-feb e del 1-mar.

In particolare sono stati selezionati esclusivamente i dati relativi a punto localizzati ad una quota superiore i 1300 m e relativi agli anni nei quali la differenza tra l'equivalente in acqua rilevato alla data del 1-Marzo risulta maggiore o uguale a quello rilevato nella campagna di misura del 1-Febrero.

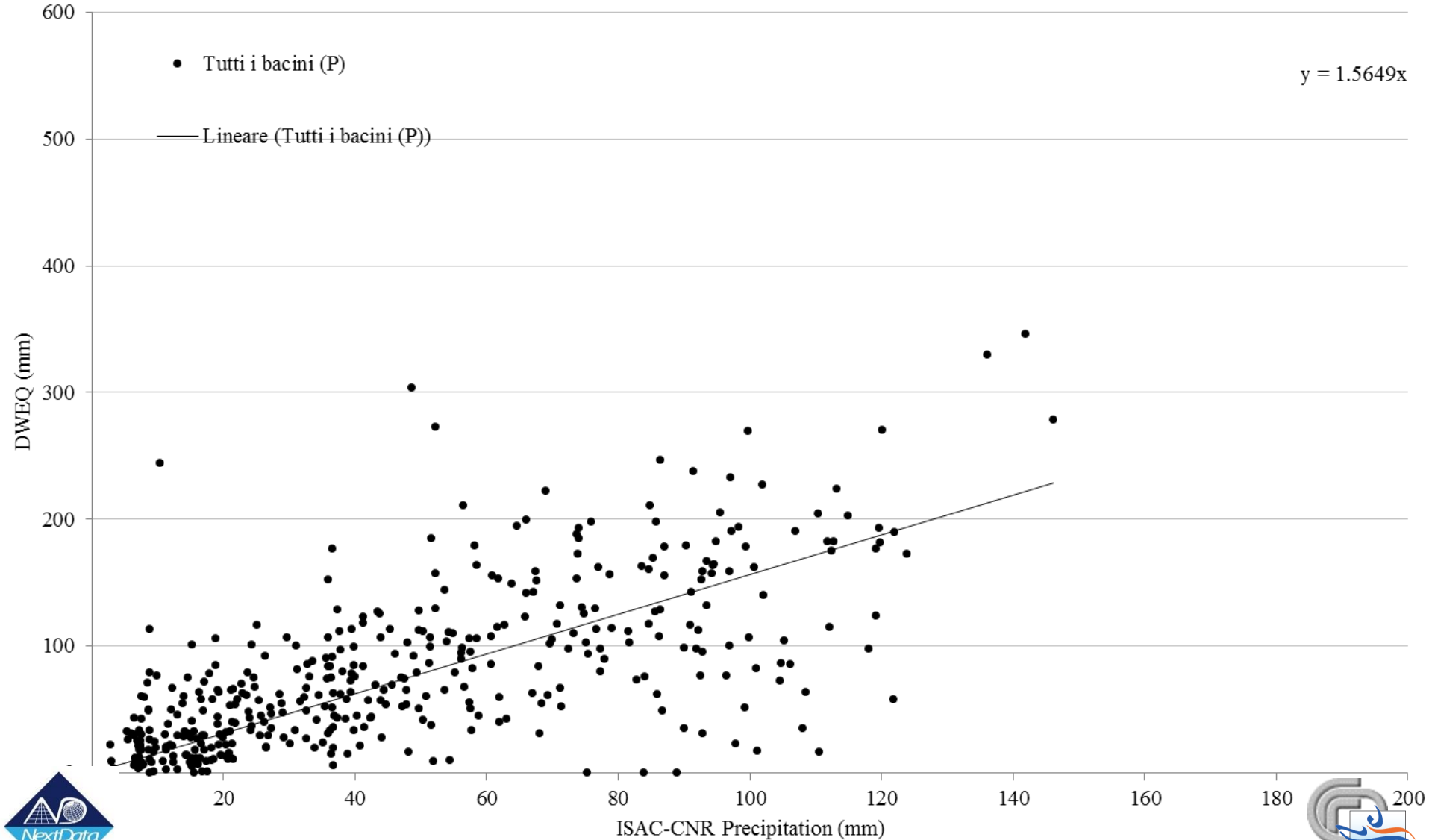
Ciascun dato è stato quindi associato alla precipitazione che i data set ad alta risoluzione forniscono per lo stesso mese nella cella della griglia dove il punto di rilievo del manto nevoso è localizzato.

Va precisato che spesso il monitoraggio del manto nevoso non viene rilevato esattamente alla data del 1-Feb e del 1-Mar, per cui la variazione del manto potrebbe risultare relativa ad un periodo leggermente diverso da quello considerato dalle mappe di precipitazione.

Inoltre è possibile, che i punti di monitoraggio del manto siano collocati in zone nelle quali il manto nevoso tende ad accumularsi fornendo così una sovrastima della precipitazione totale registrata. I dati sono presentati prima tutti assieme e poi suddivisi per sottobacino di appartenenza.

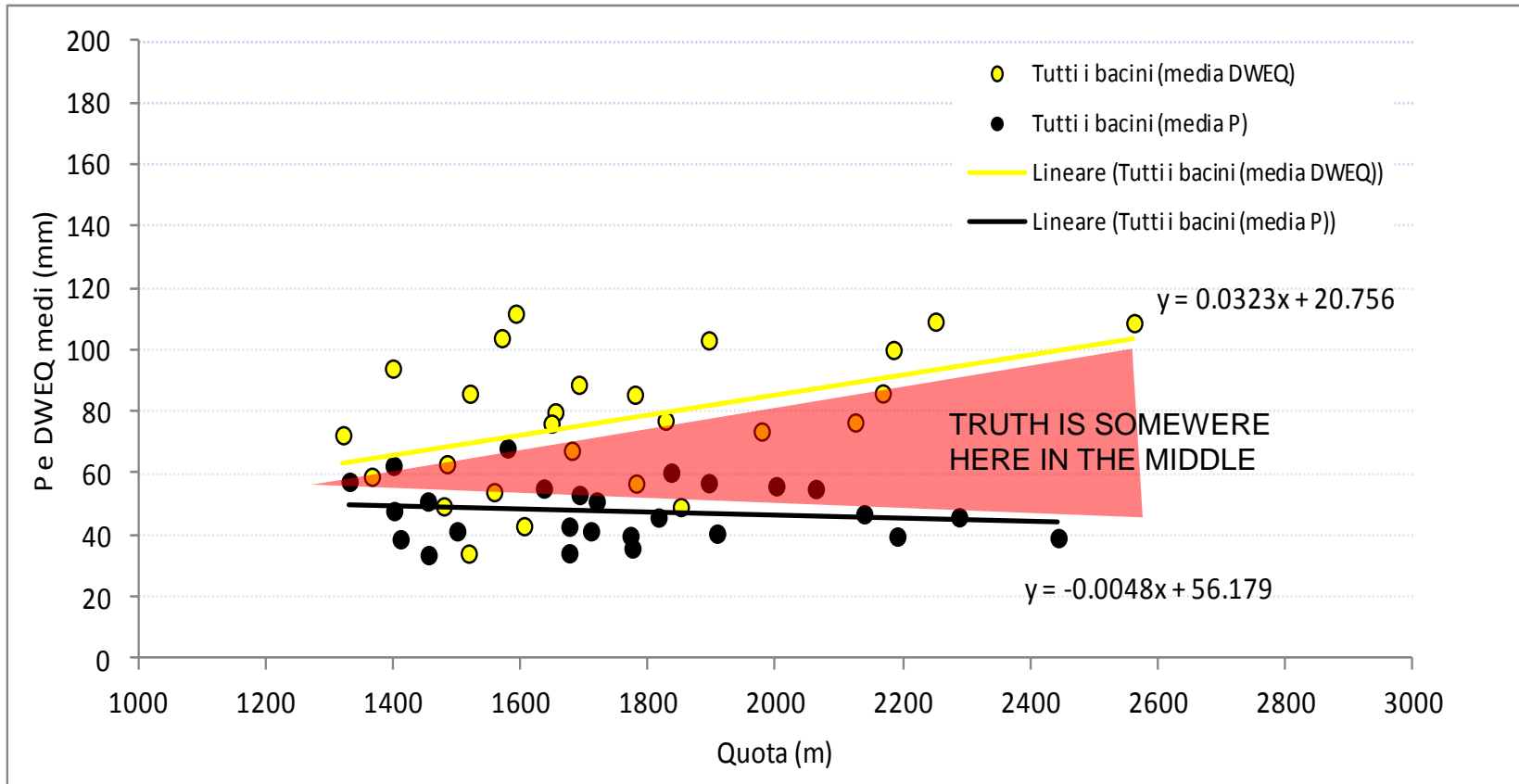
COMPARISON WITH SNOW ACCUMULATION

Snow water equivalent vs precipitation estimation



COMPARISON WITH SNOW ACCUMULATION

Snow water equivalent and precipitation estimation vs elevation (site averages)



Potential problems in snow water equivalent: snow monitoring points are located in areas where snow tends to accumulate, thus providing an overestimation of the total recorded precipitation.

Potential problems in precipitation estimates: rain gauges underestimate precipitation especially in winter months (snow) during high (...but also moderate) wind conditions.